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FROM THE EDITOR

In the face of a totally new threat to our way of life, it's been inspiring to see how scientists from different disciplines and nations have worked together, night and day, to chart a route through these dangerous times. That said, despite the best efforts of those modelling the spread of COVID-19, it's difficult to predict what the next year will look like for the UK and the rest of the world. Will lockdowns come and go? Will we find better treatments? Will anything return to 'normal'?

One thing is clear: the only thing that will bring back normality is immunity. Since January, scientists have been racing towards just that: multiple vaccines that can be manufactured quickly. Andy Ridgway met (virtually) with one team that's leading the charge. Head to p52 to find out how we'll fight the pandemic and, perhaps, stop the next one.

Sadly, the lockdown has meant that many publishers have postponed their book releases, which means we have put a pause on our books section *BookSmart*. Instead, we've put our time into a free science book club. Come and join us at **sciencefocus.com/science-book-club**, where we're giving away the first two chapters of the award-winning *Invisible Women,* along with extra interviews, insights and podcasts.

Finally, for those of you who don't subscribe, or who know someone who might benefit from a subscription to *BBC Science Focus*, we have a special three-month offer which just requires a one-off payment – it's a simple, no-strings way to get *BBC Science Focus* delivered direct to your door. There's a great longer-term offer too: six issues for just £9.99. Head to **buysubscriptions.com/SFspring3** to order online or call us on 0330 162 138 and quote code SPR3MPG, *BBC Science Focus Magazine*. Full T&Cs available online.

Daniel Bennett

Daniel Bennett, Editor

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DR STEVE BRUSATTE

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A study has shown that loneliness can trigger a craving response in our brains that is similar to hunger. Rebecca Saxe, a professor of cognitive neuroscience at MIT, gives us the lowdown. →p26

DR DEAN BURNETT

Why is social isolation so hard? Neuroscientist and author Dean explores how our brains weren't built for life alone. →p32

DR PRAGYA AGARWAL

We all have biases that hold sway over our lives. Behavioural scientist Pragya explains where these mental shortcuts stem from, and how we might build technology free from our shortcomings. →p64

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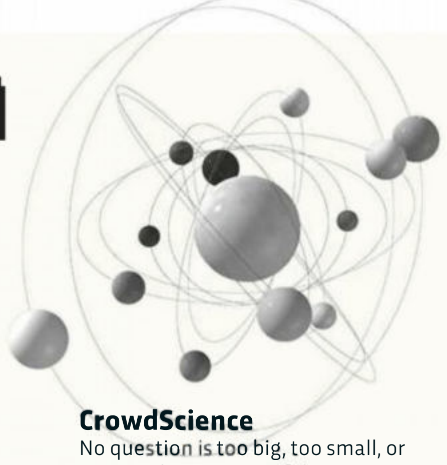
ON THE BBC THIS MONTH...

The Great British Intelligence Test

This *Horizon* special reveals the results of The Great British Intelligence Test, which saw 250,000 people from around the nation take part online. Dr Hannah Fry and Dr Michael Mosley discuss the science of intelligence, and what the test's findings mean for our future.

BBC Two, check *Radio Times* for details



CrowdScience

No question is too big, too small, or too silly for the *CrowdScience* team. This month, the programme answers questions from listeners on space, particles, maths, toilets and tickling.

BBC World Service, new episode every Friday

Between Life And Death

This BAFTA award winning documentary from 2010 is available on BBC iPlayer. It follows doctors working in the brain injury unit at Addenbrooke's Hospital, Cambridge, who can interrupt, and even reverse, the process of death.

BBC iPlayer

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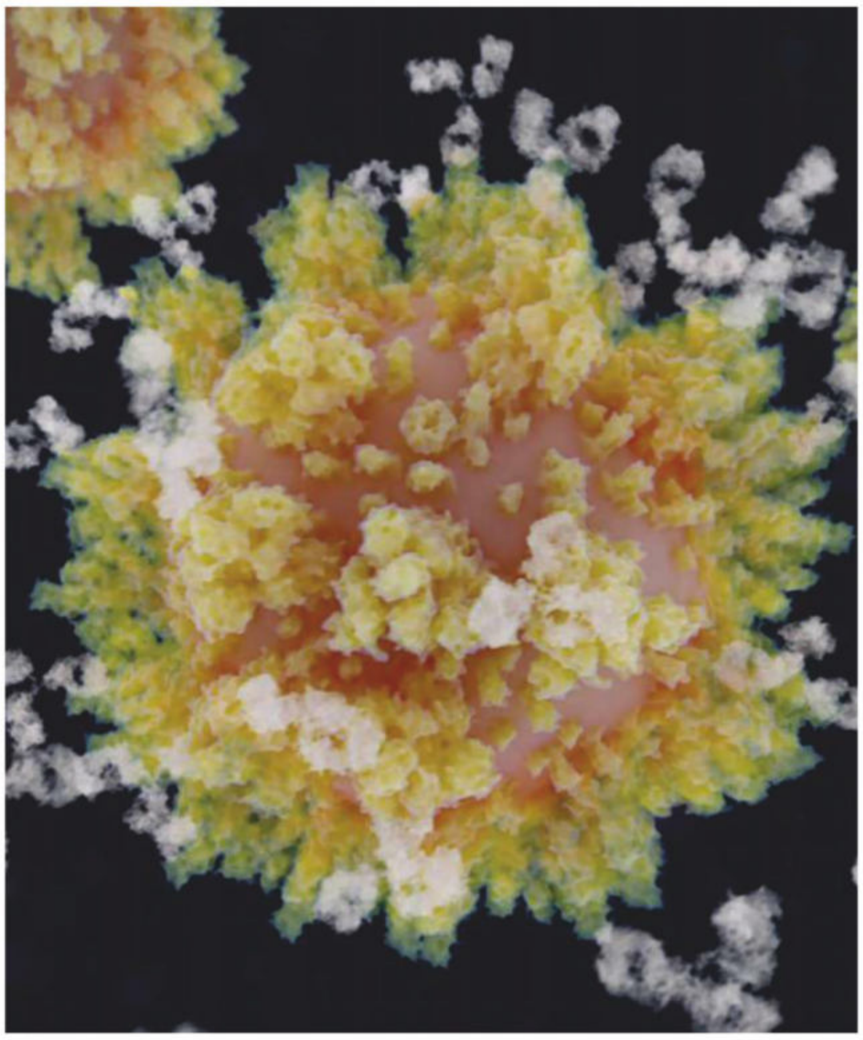

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When humans move out, nature quickly moves in.

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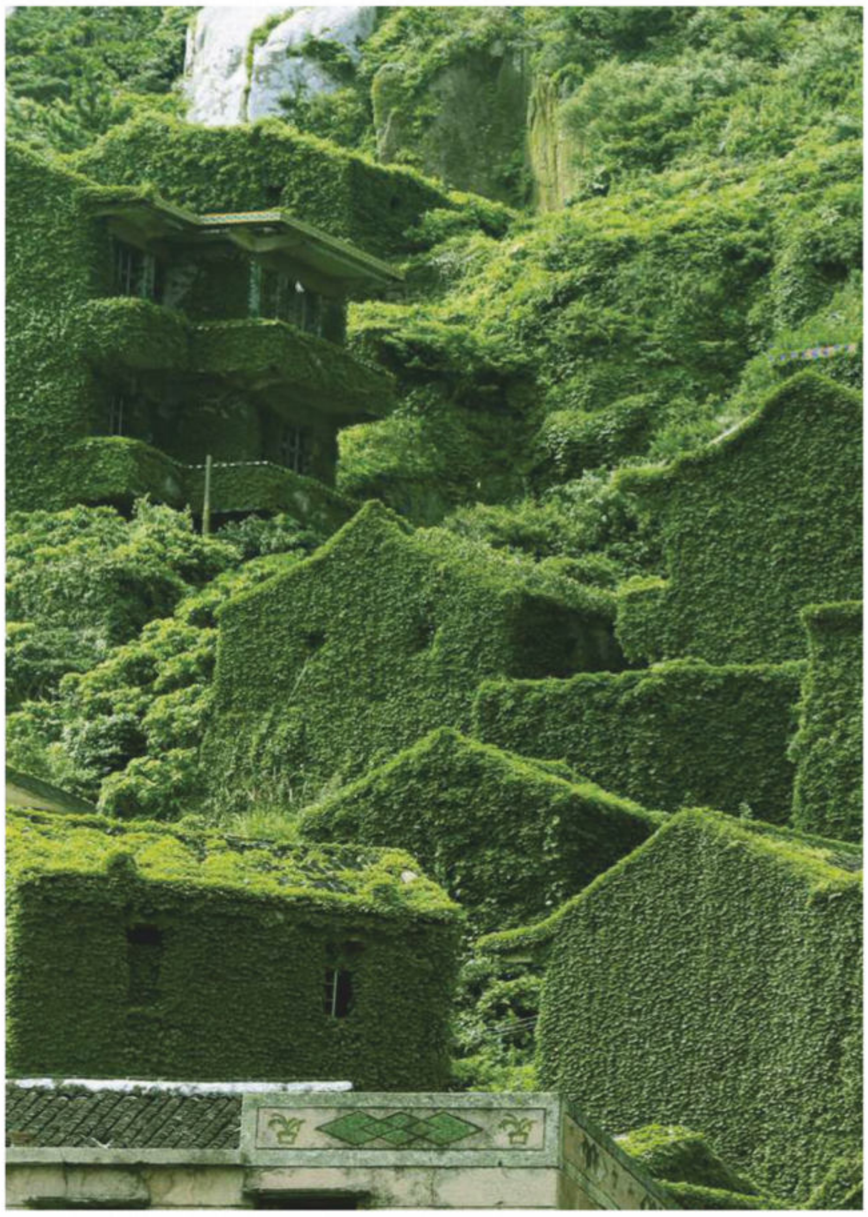
LIFE FINDS A WAY



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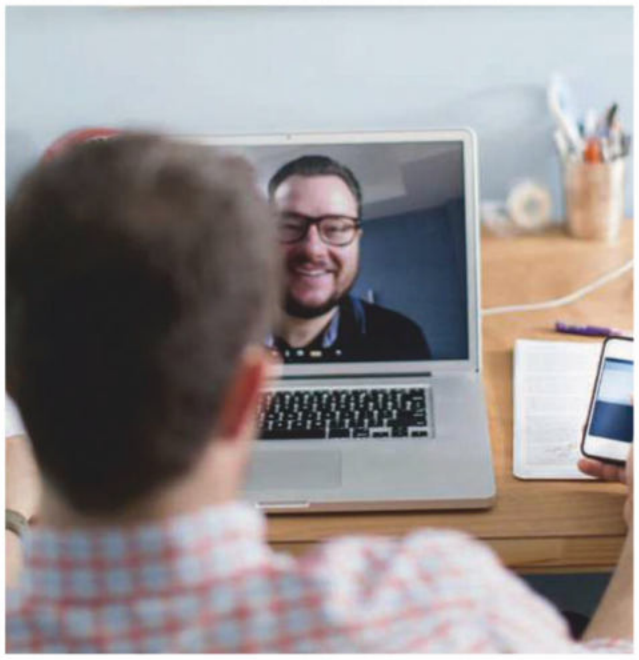
The science tips that will help you stay happy, healthy and productive while working at home.



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“I HAVE FRIENDS AND FAMILY WHO ARE TEACHERS. THEY ARE GODS AND GODDESSES. NOTHING PHASES THEM”

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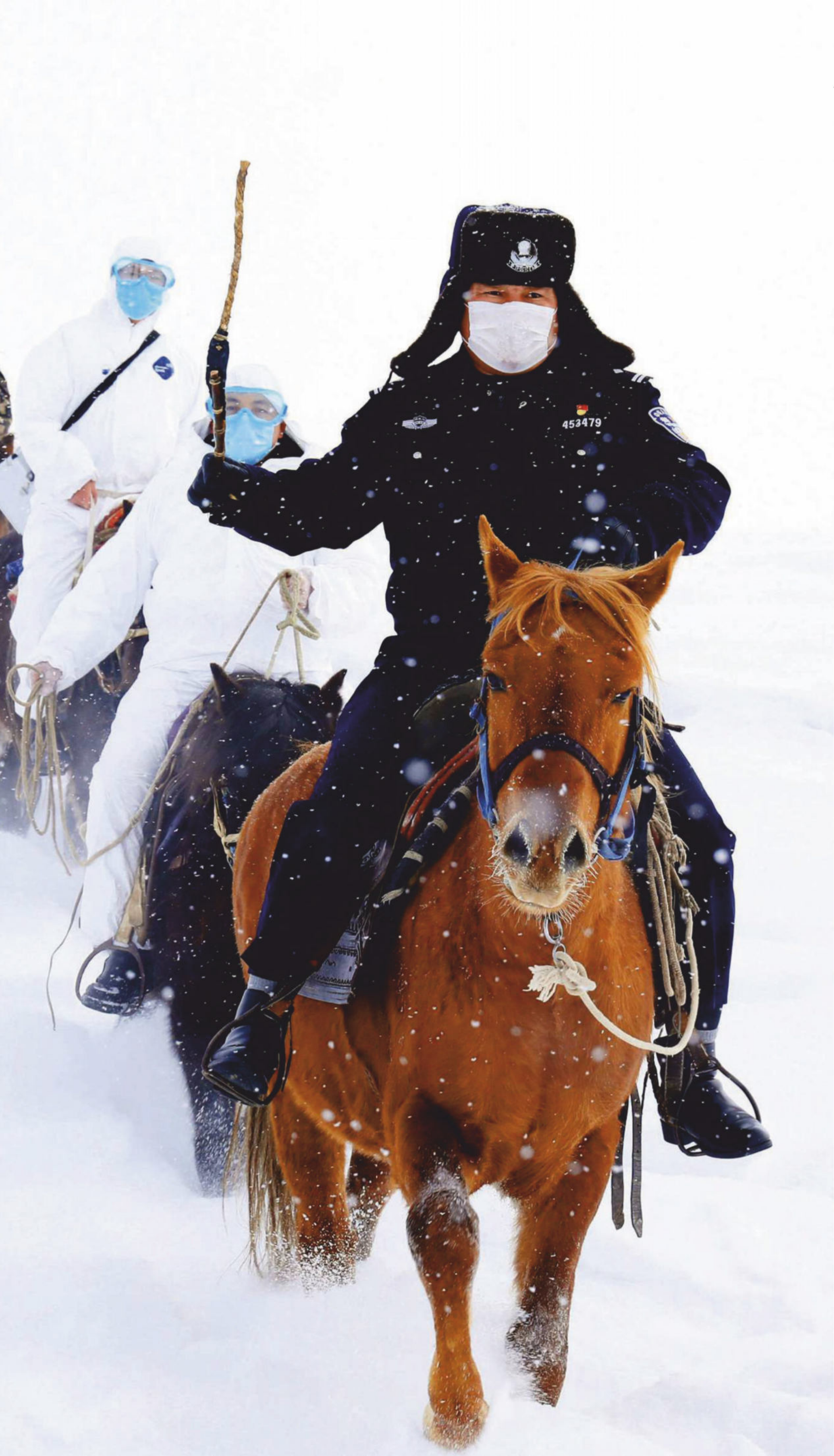

EYE OPENER

Medics on a mission

FUYUN COUNTY, CHINA

If you didn't have access to modern technology, how would you know about the risks posed by COVID-19? Or even that a new virus had taken hold and had become a pandemic?

Travelling through rough, snowy conditions on horseback to remote parts of China's Xinjiang region in the northwest of the country, these Chinese authorities were on a mission to reach the isolated nomadic families in the Altai Mountains. Wearing face masks and hazmat suits, this was no easy journey. They travelled in February, with snow that was so deep in places that parts of the trek had to be completed on foot.

The team was comprised of police officers, medical workers and military troops, and their aim was to carry out some basic health tests and to educate the families about prevention and treatment measures, if the virus were to reach their community.

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EYE OPENER

Tree of life

PORT ANGELES, USA

This sitka spruce tree is just one of thousands of trees along 117,482km (73,000 miles) of coastline at the Washington Olympic National Park. For the rangers, it was of no particular significance. Until, that is, a recent outpouring of interest on social media from people all over the world, who began calling it the 'Tree of Life' or 'Tree Root Cave'.

"What makes it an enigma, I'll say, is the stream that flows out directly from underneath the tree," explains Jared Low, lead coastal interpreter for the Olympic National Park. This is what creates the cave-like illusion. "It's not a cave, just an eroded point in the bluff. But it certainly is aesthetically mesmerising."

Most sitka spruces start from a seed that lands on a log, called a 'nurse log', Low explains. "Slowly a tree starts to grow and as it gets bigger the roots reach out, looking for nutrient-rich soil. Over time, the nurse log decomposes, leaving this wide root system."

ALAMY

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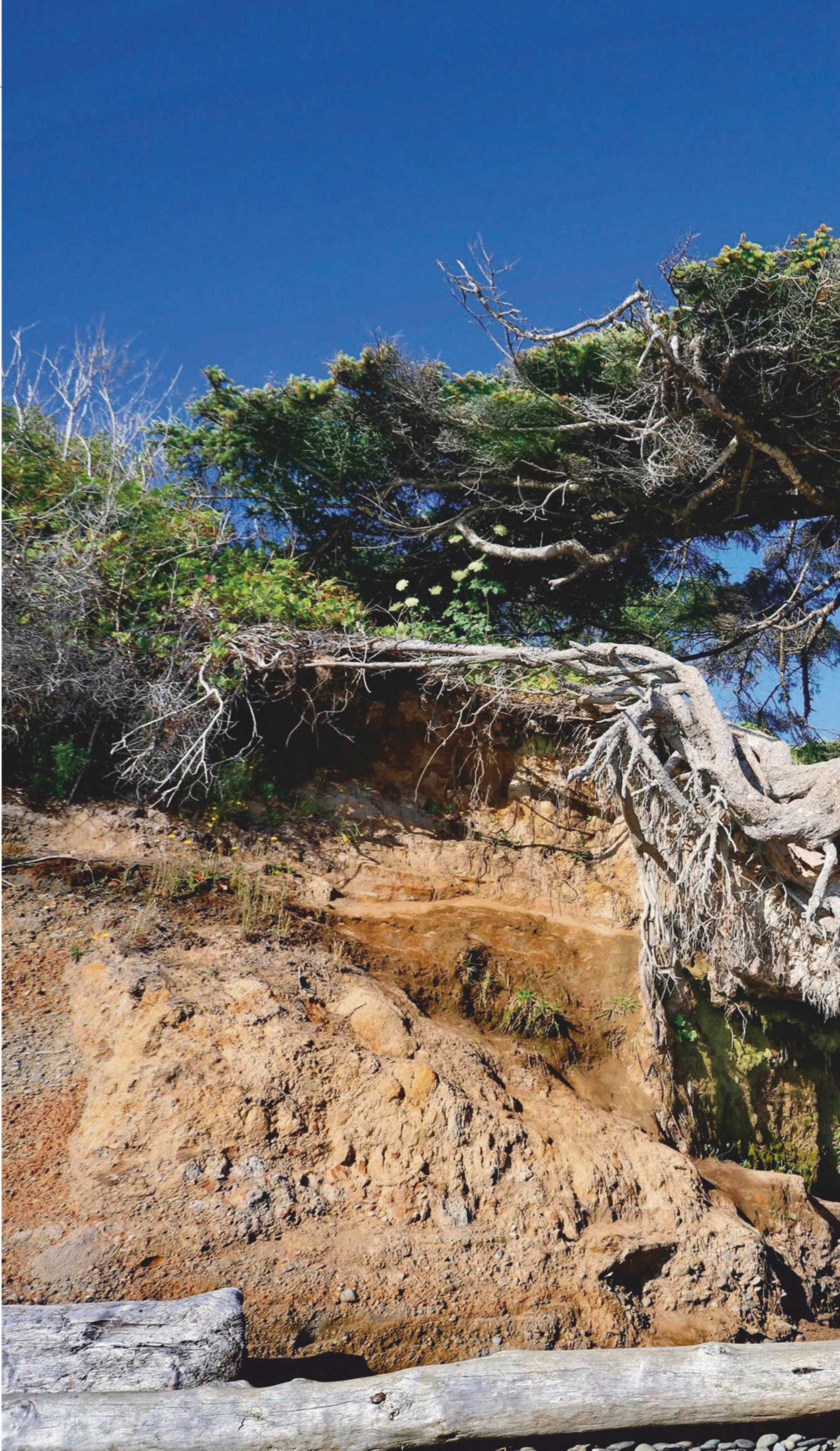

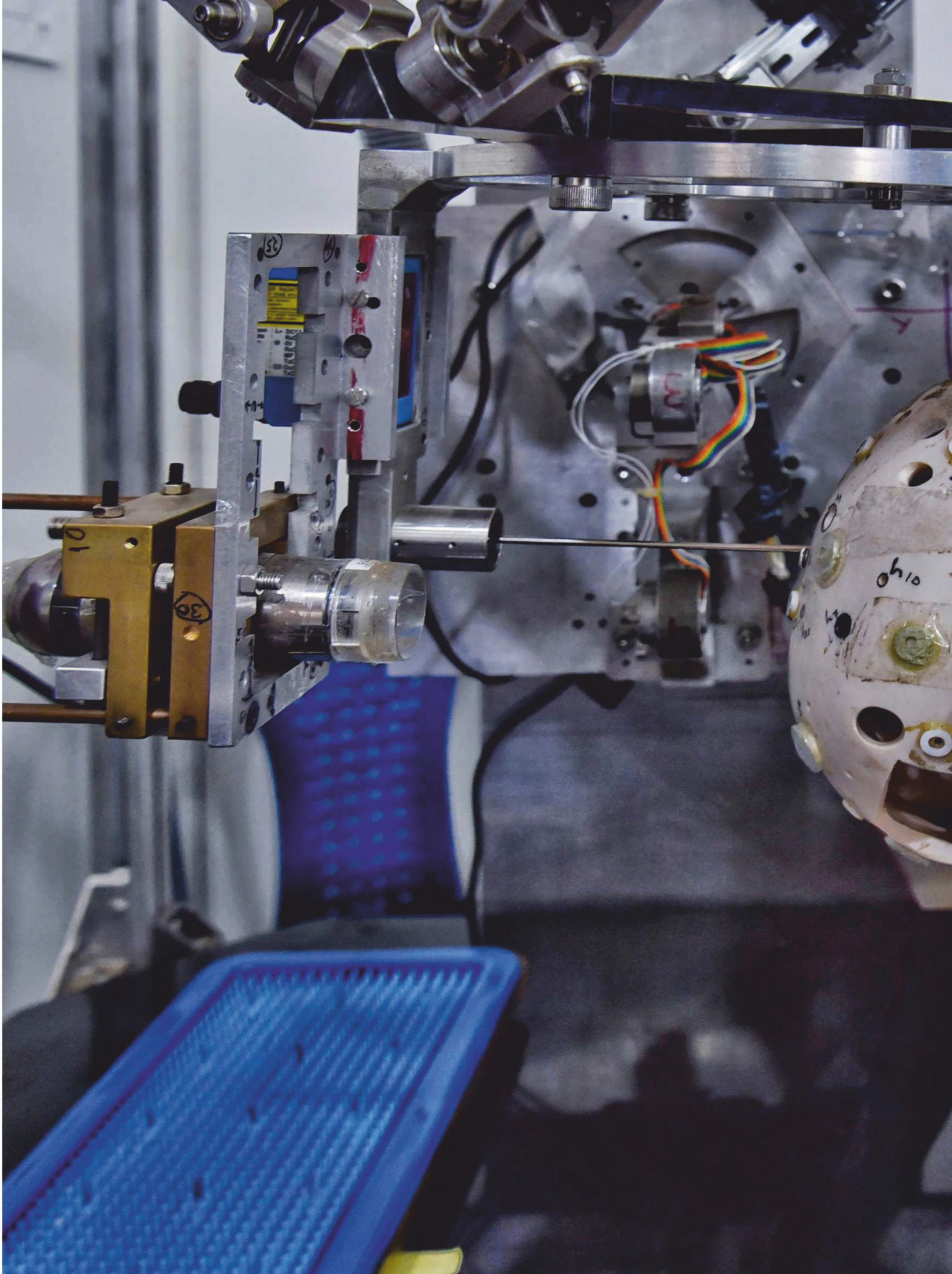
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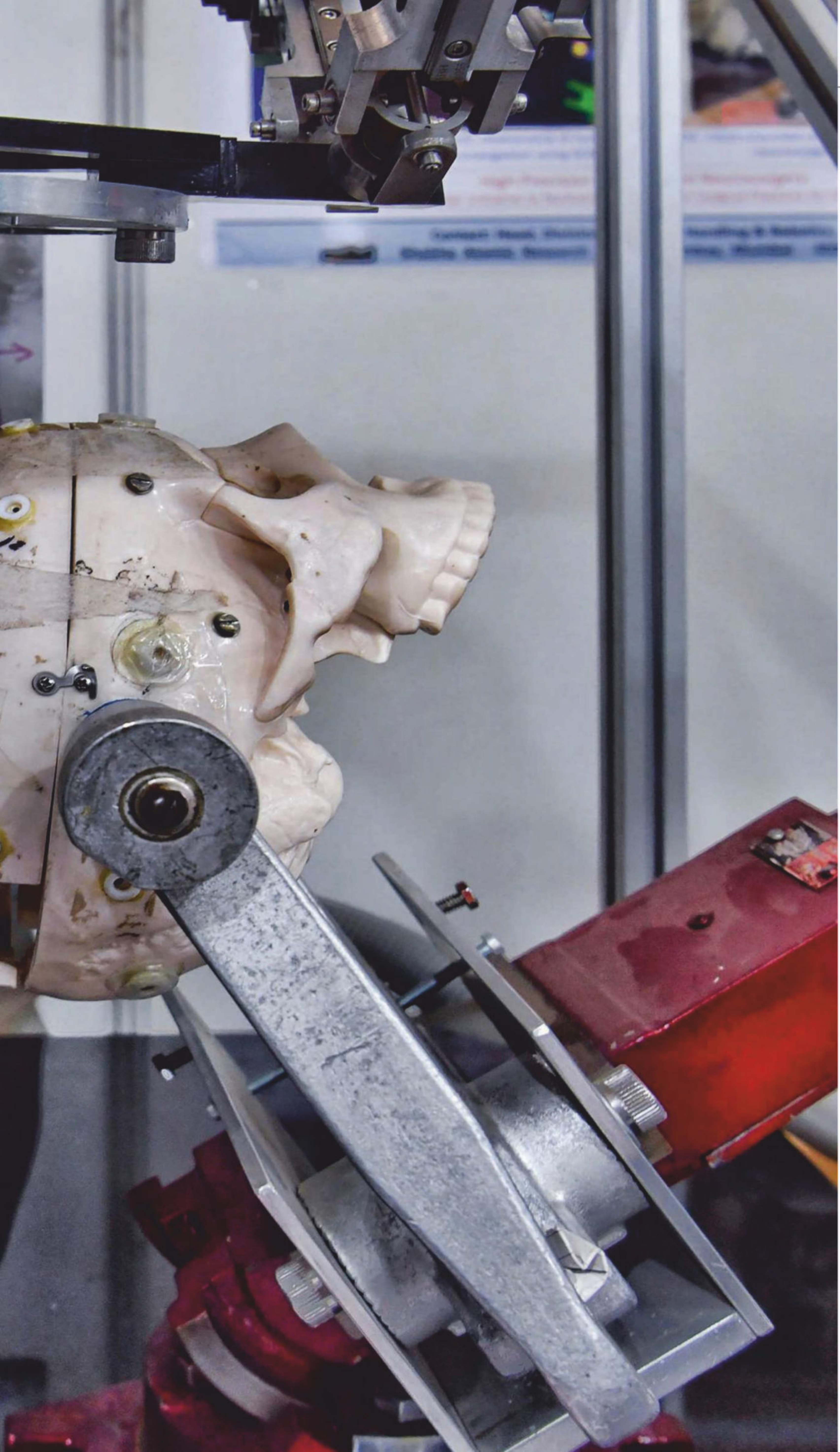

EYE OPENER

Robotic precision

MUMBAI, INDIA

This rather brutal-looking machine is actually a prototype of a robot that could eventually be used for delicate neurosurgery procedures. Seen here at the National Institute of Mental Health and Neurosciences in India, it has been developed by the Bhabha Atomic Research Centre (BARC).

Instead of a model of a skull, imagine a real person securely held in place, where this robot can reach any point, from any angle. Its design makes it ideal for complex manoeuvres, and it's hoped that neurosurgeons will be able to achieve biopsies of extremely small, deep-rooted tumours. "It's capable of pinpointing where it is in relation to the brain," explains Dr Peter Bentley, computer scientist at University College London. "They're using MRI scans to build up a 3D model of the brain, from which they can plan the surgery. They can even do virtual surgery in a 3D simulation, before the robot does it for real."

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LETTER OF THE MONTH

This fly orchid not only looks like an insect, it also releases a scent that smells like a female wasp

Dropping doppelganger

I was fascinated to read about the grass in South Africa's Cape Province (March, p50) that has somehow managed to produce seeds that mimic the look and scent of antelope droppings! Now I'm no expert but I've never seen a plant that has eyes and a nose, so I'm left wondering what type of wizardry does it use?
Mark Smith, *Derby*

True, plants don't experience the world like we do, but they still respond to all kinds of sensory cues, and they face the same selection pressure as animals. This grass hasn't purposefully set out to create seeds that mimic antelope droppings, but a lucky genetic mutation in the past proved to be beneficial, and so this trait has stuck around and been honed over time. In this way, the plant kingdom has evolved many devious flowers that trick other species. Over thousands of years, orchids have turned into fabulous copies of flies and bees, and have perfected the scent of rotting flesh and much else besides.
Ben Hoare, *wildlife writer*

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **Roku Streaming Stick+**. Simply plug it into your TV and you can stream 4K and high-definition content across thousands of channels. With its voice-activated remote, you can easily pick up your telly-watching where you left off. **roku.com**

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Laws and licences

I was surprised to read that Jaguar Land Rover anticipate that people may not want to drive, nor own cars, in future (March, p40). This crossed my mind recently when I applied to sit my driving test again (third time's the charm!). However, I see that the autonomous shuttle they have developed is fitted with a "steering wheel and pedals, just in case". My question is, will it be necessary for people who are 'driving' autonomous vehicles to hold a driver's licence?
Nicola Kiely

Every 'driverless' car currently on public roads actually needs a driver. They're fitted with standard controls – steering wheel and pedals – in case anything goes wrong, so you need a licence before you can operate it. But in the future, who can say?

Once it's proven that a car can drive itself without putting people at risk, the law may change to allow manufacturers to build cars without steering wheels (or at least hidden ones). Or lawmakers may decide an autonomous vehicle on public roads should always have someone behind the wheel who can operate the car in case of emergency. A sticking point will be liability. If a car is fully autonomous, who's at fault if an accident happens?
Daniel Bennett, *Editor*

> “WE CANNOT JUST DO AWAY WITH ALL OUR BIASES. BUT WE CAN DO AWAY WITH THE STEREOTYPES, PREJUDICES AND DISCRIMINATION THAT IS LINKED TO SOME OF THE BIASES WE CARRY”
>
> PRAGYA AGARWAL, p64

Ride or die

I was amused by the conclusion that research at the University of Otago, New Zealand, arrived at – I quote: “cycling to work can reduce your likelihood of dying by up to 13 per cent” (March, p19). This seems a great chance to achieve immortality. Just a pity that one has to continue working!

R J Minns

The only way is up

February’s *Reality Check* asked whether the mid-40s was the most miserable time of our lives (p32). This really struck a chord with me, as someone who is in his early-40s. I can see Dr Dean Burnett’s point that the famed ‘happiness curve’ may not exist. However, most people around me in their late-40s are not as happy as they were when we were all younger. This is indeed caused by tight finances due to mortgages and kids, and the onset of aches and pains. I myself have started to suffer from bad knees. All of this combined is making me feel far more unhappy than I have ever been, so I am hoping the curve is real and look forward to an upswing in the next decade or so!

Luke Russell

Ride to work and become immortal?

Prejudice paradigm

Dr Christian Jarrett’s article, *The Mystery Of You* (February, p53) presents the puzzle: what makes us self-aware? Equally you could ask: why are we self-aware?

If we are always a step back from that which we perceive and are aware of our own ‘perceiving’ then that allows for us to compare and contrast and thus develop some form of aesthetics and so eventually an ‘identity’. This got me thinking of Dr Adam Rutherford’s interview in the same issue (p92), and the problem of racism, such that it’s difficult to reason with a racist given their racism is like an ‘identity dependency’.

For them to reject their racism would take that extreme act of consciousness: a paradigm shift. Only a few people have managed that successfully. One of them being Einstein, I would suggest. And very few of us, let alone a racist, is an Einstein.

Michael Griffiths

Bridge the funding gap

I live fairly close to Portpatrick, the proposed link on the Scottish side of the Scotland-Ireland bridge covered in your March issue (p18). I’ve yet to hear anyone say they wanted it. They would be much happier if the umpteen billions were spent on the struggling roads which would give access to it!

Kathy Turner

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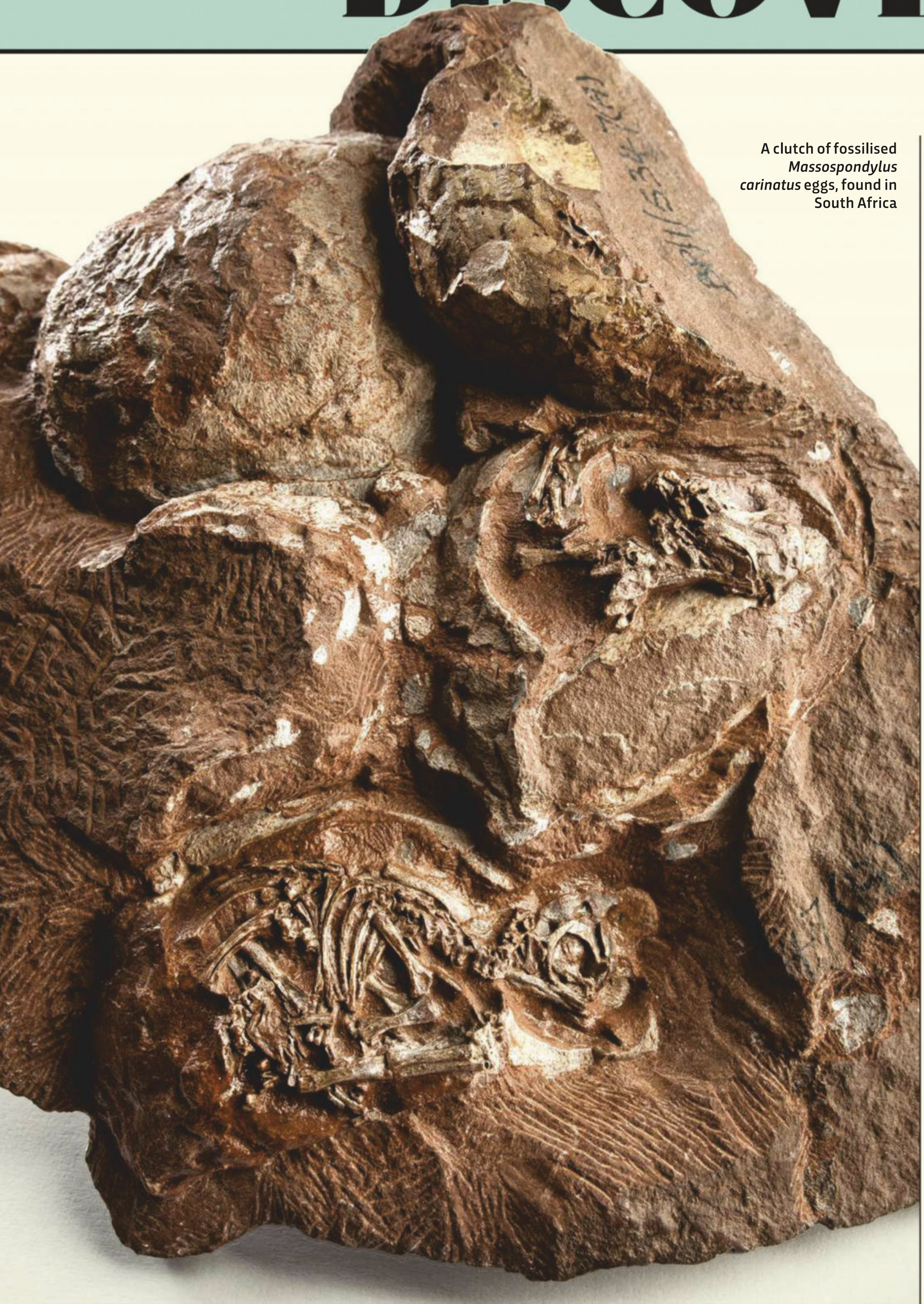


A clutch of fossilised *Massospondylus carinatus* eggs, found in South Africa

PALAEONTOLOGY

LAB CREATES DETAILED 3D DIGITAL MODEL OF SOME OF THE OLDEST-KNOWN DINOSAUR EMBRYOS

The recreation reveals that the dinosaurs' skulls developed in a similar way to those of today's chickens, crocodiles and lizards

An international team of scientists, led by the University of the Witwatersrand in South Africa, built a detailed 3D model of the skulls of some of the world's oldest known dinosaur embryos. To do this, they used scanning technology powered by the particle accelerator at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France.

The embryos were first found in Golden Gate Highlands National Park, Free State Province, South Africa, in 1976. They belong to *Massospondylus carinatus*, a five-metre-long herbivore that lived in the region around 200 million years ago. Thanks to their small size and extremely fragile nature, the embryos are particularly difficult to study using conventional methods.

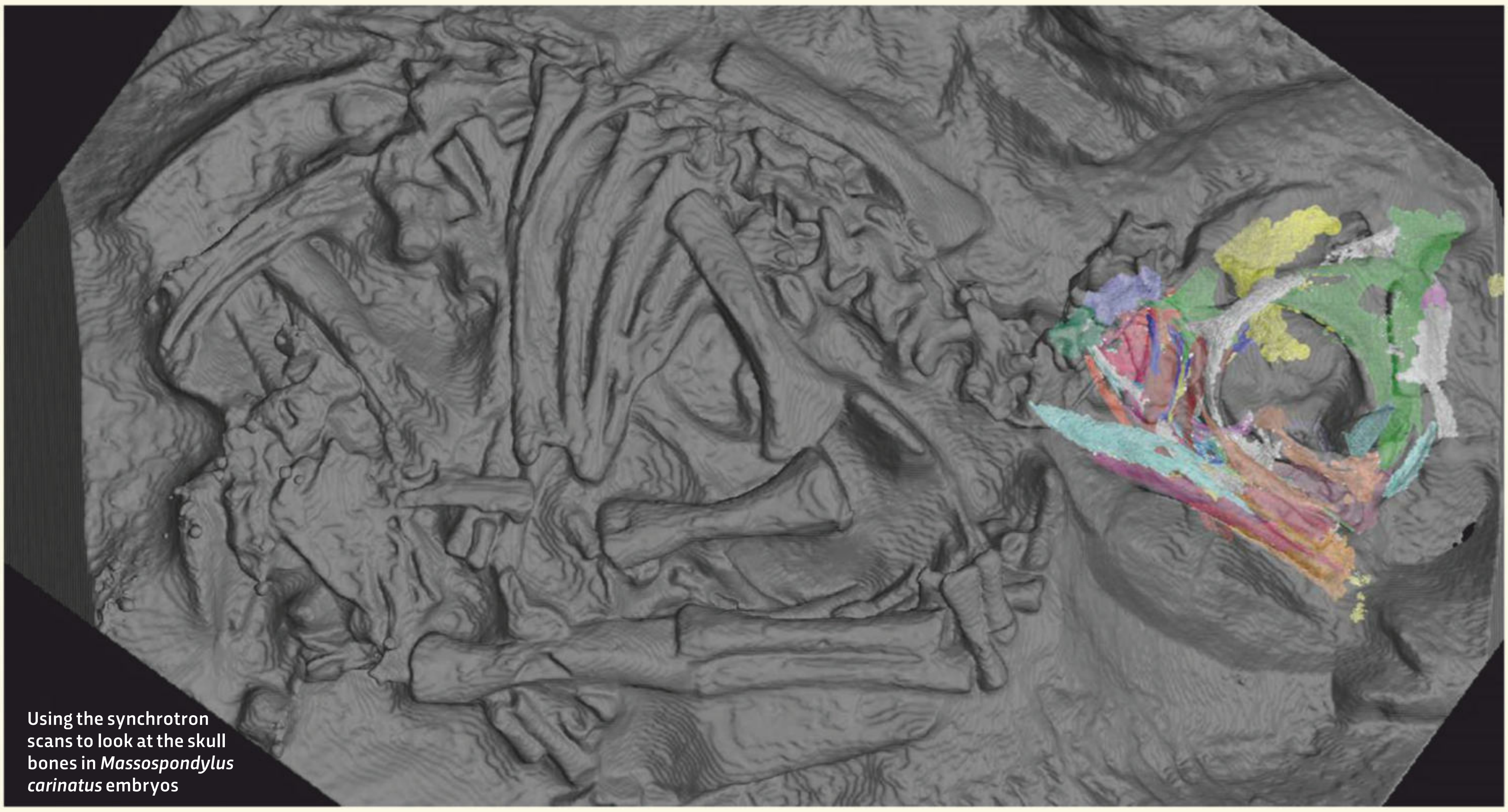
To overcome these problems, lead author Dr Kimi Chapelle and

High salary, high emissions Richer people splash the cash on high-carbon transport p24 **Starved of contact** Social isolation triggers similar cravings to hunger p26 **Spider show-offs** Scientists spot seven new species of peacock spiders p28

News in brief

BABIES LOVE HUGS

A study from Toho University in Tokyo, Japan, suggests that babies as young as four months old enjoy receiving a hug from their parents. The research found that when parents hugged their child, both individuals experienced reduced heart rates – as measured by an increase in heartbeat intervals on an electrocardiogram – suggesting that they felt more relaxed. When the child was simply being held, the same calming effect was not seen. In contrast, when the infant was hugged by a female stranger, their heart rate was unaffected. According to the researchers, this offers evidence about the importance of hugging in the bonding process between young babies and their parents.



Using the synchrotron scans to look at the skull bones in *Massospondylus carinatus* embryos

Prof Jonah Choiniere, both from the University of Witwatersrand, took the embryos to the ESRF. This 844-metre-long circular particle accelerator can accelerate electrons to near the speed of light, to produce powerful X-ray beams that can be used to non-destructively scan matter in high detail. The scans created were so detailed that individual bone cells were visible. The dataset produced was so vast that it took the team nearly three years to process it and turn it into a detailed 3D model.

"No lab CT scanner in the world can generate these kinds of data," said Dr Vincent Fernandez, one of the co-authors and scientist at the Natural History Museum in London. "Only with a huge facility like the ESRF can we unlock the hidden potential of our most exciting fossils. This research is a great example of a global collaboration between Europe and the South African National Research Foundation."

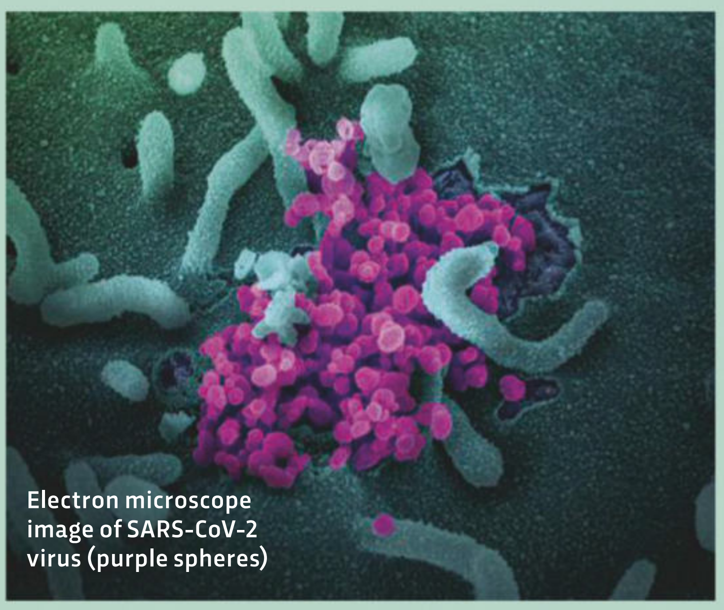
> "Only with a huge facility like the European Synchrotron Radiation Facility can we unlock the hidden potential of our most exciting fossils"

Upon studying the data, Chapelle noticed several similarities with the developing embryos of living dinosaur relatives – crocodiles, chickens, turtles, and lizards. The team also found that each embryo had two types of teeth preserved in its developing jaws. One set was made up of very simple triangular teeth that would have been reabsorbed or shed before hatching, just like geckos and crocodiles do today. The second set of teeth were similar to those of adult *M. carinatus*, and would be the ones that the embryos hatched with. This indicates that dinosaurs developed in the egg just like their reptilian relatives, whose embryonic developmental pattern hasn't changed in 200 million years.

"It's incredible that in more than 250 million years of reptile evolution, the way the skull develops in the egg remains more or less the same," said Choiniere. "Goes to show – you don't mess with a good thing!"

BRET ELOFF, DR KIMI CHAPELLE, GETTY IMAGES

A researcher tests for the presence of COVID-19 antibodies



Electron microscope image of SARS-CoV-2 virus (purple spheres)

CORONAVIRUS

Test to determine if you've had COVID-19 is nearly here

Prime Minister Boris Johnson announced on 24 March that the government had ordered 3.5 million antibody test kits, which are able to identify in 10 minutes whether someone has had the COVID-19 infection. The kits can be used at home, involving just a finger prick to produce a blood sample that is then tested for immune cells specific to the coronavirus.

A positive result on the test would mean that a person had successfully fought off the SARS-CoV-2 virus and would have some immunity against future infection – though for how long that immunity would last is still unknown. For some viruses, such as smallpox or polio, one instance of infection is enough to give a person lifetime immunity. Others, such as norovirus, result in immunity against re-infection for up to two years, and for common colds, the body's immunity can fade after just months.

The antibody tests bought by the government won't detect a current infection, but they'll look for a type of immune cell – an antibody – that the body creates to tackle new infections. An antibody is produced by the body as part of an immune response and is specific to fighting a particular pathogen.

It is thought that, once a person with coronavirus antibodies has been identified, their blood plasma could be used as a treatment for others infected with the virus.

As soon as the antibody tests have been validated, it is likely that they will be distributed for use first by key workers, before being made available to the wider public.

"[The tests] will tell us who among individuals in our NHS and other essential workforces are immune to the virus and, therefore, safe to return to their vital work," said David Wraith, director of the Institute of Immunology and Immunotherapy at the University of Birmingham.

Following that, the tests could be given to people who are particularly vulnerable, said Paul Hunter, a professor of health protection at the University of East Anglia. If they were immune, they could relax the measures at which they are self-isolating. Knowing who is immune will help those people stop worrying whether or not they are putting themselves or their families at risk, Hunter said.

These tests will also be of use when a vaccine first becomes available, as it will initially be in short supply. "An antibody test would allow the vaccine be used just for people who are not already immune," said Hunter.

How does the antibody test work?

The antibody tests purchased by the government are known as 'serological', meaning they test blood serum – a component of blood plasma.

A blood sample is collected by pricking the end of the patient's finger using a small needle.

The sample is then placed on a surface that contains proteins that mimic those found on the SARS-CoV-2 virus.

If there are COVID-19 antibodies present in the blood plasma, these bind to the proteins on the test and trigger a colour change in a small window, similar to that of a pregnancy test. This is considered a positive result.

No colour is a negative result, which would indicate that the person has not produced antibodies to fight the coronavirus.

Unfortunately, a negative result on the antibody test does not necessarily mean that the individual is definitely not infected. If a person had recently contracted the virus, perhaps within three days prior to taking the test, their body may not have yet started producing antibodies at a high enough concentration to be detected by the test.

GETTY IMAGES X2, NIAID-RML, SERGEY KRASOVSKIY

CLIMATE CHANGE IS BAD NEWS FOR NIGHTINGALES, TOO

Scientists at the University of Madrid have found that the average wing length of nightingales has decreased over the past 20 years. They think that later onset of spring along with intense summer droughts are shortening the breeding season for the birds, so they produce smaller clutches with reduced wing size. In winter, the birds fly from breeding grounds in Europe and parts of Asia to sub-Saharan Africa, but the team found that the shorter-winged birds were less likely to make the return trip. The shortening wings might be an example of 'maladaptation', where the response to a changing environment is harmful rather than helpful.

PALAEONTOLOGY

New feathered raptor lived just before the asteroid strike

A newly discovered raptor shows that these dinosaurs stalked the southwest of North America right up to the bitter end.

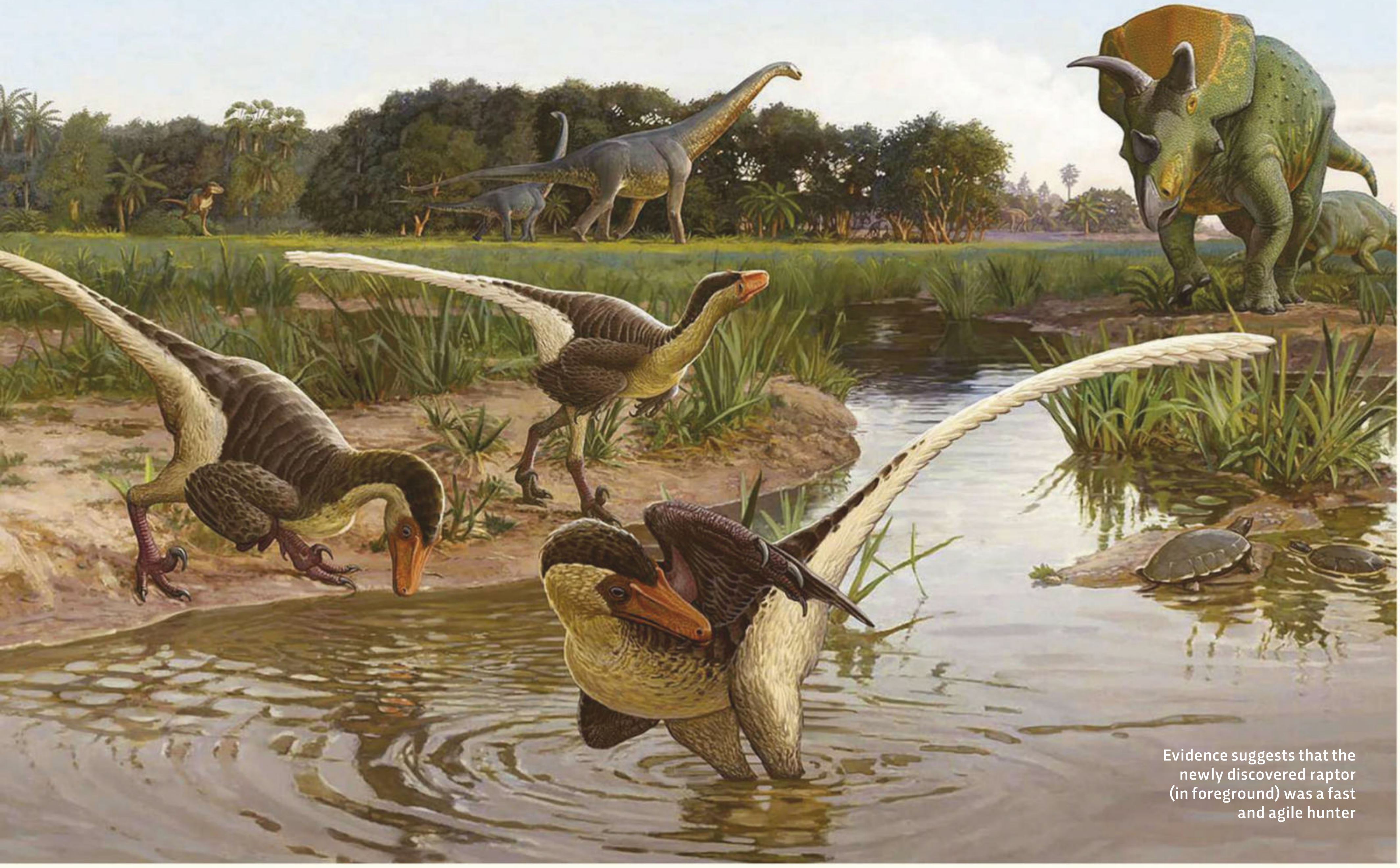
The raptor was discovered from a 67-million-year-old fossil, dating it to within a million years of the cataclysmic event that killed off all non-flying dinosaurs. It has been named *Dineobellator notohesperus*, which means 'Navajo warrior from the southwest', in honour of the people who live in the region where this dinosaur once roamed. It belongs to a family of dinosaurs known as the dromaeosaurids, the most famous of which is *Velociraptor* – that's why these dinosaurs are commonly known as 'raptors'. *Dineobellator* was a lightly built meat-eater, measuring about two metres in length. Features on the animal's forelimbs suggest that it boasted strong arms and claws – handy for holding onto prey, or grappling with other dinosaurs.

Its tail was also unusual. Unlike other raptors, it could move its stiff tail at its base, using it almost like a rudder as it raced across the ground.

"Think of what happens with a cat's tail as it is running," said Steven Jasinski, who led the study while completing a PhD at the University of Pennsylvania. "While the tail itself remains straight, it is also whipping around constantly as the animal is changing direction. A stiff tail that is highly mobile at its base allows for increased agility and changes in direction, and potentially aided *Dineobellator* in pursuing prey, especially in more open habitats."

And, just like *Velociraptor*, it looks like *Dineobellator* sported feathers. Bones from the dinosaur's forearm had quill knobs – small bumps on the surface where feathers would be attached by ligaments.

"As we find evidence of more members possessing feathers, we believe it is likely that all the dromaeosaurids had feathers," said Jasinski.



Evidence suggests that the newly discovered raptor (in foreground) was a fast and agile hunter

TECHNOLOGY

Shanghai buses blasted with UV in an effort to contain coronavirus

In Shanghai, China, a public transport company has installed powerful ultraviolet lamps in its garages in order to disinfect its buses. This is in an attempt to halt the spread of the coronavirus that is currently rampaging across the globe.

The cleaning process is controlled remotely and sees the buses drenched in an eerie blue light. It takes around five minutes to treat each vehicle.

Ultraviolet light is routinely used in hospitals, water treatment plants and aeroplanes as a means of sterilisation, as it damages viruses' genetic material and prevents them from reproducing. It is known to be effective against other coronaviruses such as SARS, but it is as yet unclear whether it will have the same effect on SARS-CoV-2.

The World Health Organization warns that UV light should not be used to disinfect skin, as it can cause irritation and damage to cells.

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BREASTFEEDING MAY LEAD TO FEWER VIRUSES IN INFANTS

Consuming even small amounts of breast milk can protect babies from a range of viruses by increasing the viral populations in their guts, a study at the University of Pennsylvania has found.

The researchers measured the numbers and types of viruses found in the first stool (meconium), and subsequent stools of newborns in both the United States and Botswana. They found that shortly after delivery, babies had little or no viral colonisation, but after just one month this shot up to as much as one billion viruses per gram of gut contents. Most of this first wave of viruses are predators that grow in the first bacteria that colonise the infant gut. Later, at four months, viruses that can potentially make humans ill became more prominent in the babies' stools. The team found that breastfeeding, even when combined with formula-feeding, helped suppress the accumulation of these potentially pathogenic viruses.

PRIMATES

Ancient monkeys may have voyaged across the Atlantic Ocean on rafts

Fossilised monkey teeth unearthed deep within the Peruvian Amazon suggest that ancient monkeys journeyed there from Africa, according to a study at Keck School of Medicine, in Los Angeles.

The fossilised teeth belong to a monkey species previously unknown to science. The researchers have named the species *Ucayalipithecus perdita,* and found that it belongs to an extinct family of African primates known as parapithecids. One plausible explanation, according to the team, is that the monkeys made the trip on floating rafts of vegetation that broke off from coastlines, possibly during a storm. At the time, the landmasses of Africa and South America were closer together, which means the voyage may have been about 1,450km (900 miles).

Based on the age of the Amazonian site and the similarity of *U. perdita* to its fossil relatives from Egypt, it is estimated that the migration might have occurred around 34 million years ago.

"We're suggesting that this group might have made it over to South America right around what we call the Eocene-Oligocene Boundary, a time period between two geological epochs, when the Antarctic ice sheet started to build up and the sea level fell," said study leader Prof Erik Seiffert. "That might have played a role in making it a bit easier for these primates to actually get across the Atlantic Ocean."

The monkey would have been tiny, similar in size to a modern-day marmoset.

"The thing that strikes me about this study, more than any other I've been involved in, is just how improbable all of it is," said Seiffert. "The fact that it's this remote site in the middle of nowhere, that the chances of finding these pieces is extremely small, to the fact that we're revealing this very improbable journey that was made by these early monkeys, it's all quite remarkable."

***Ucayalipithecus perdita* was identified by fossilised teeth (inset). The monkey would have been about the size of a modern marmoset (main image)**

GETTY IMAGES X2, ERIK SEIFFERT

BLOOD TEST TO HELP CATCH CANCER EARLY

An international research team has developed a blood test that can accurately detect over 50 types of cancer, often before symptoms start to show. The test can also determine the tissue in which the cancer originated and reveal its type.

All cells, including tumour cells, shed cell-free DNA (cfDNA) into the bloodstream, and this test looks at the chemical changes, called methylation, within the cfDNA. Abnormal methylation patterns and the resulting changes in gene expression can contribute to tumour growth.

"This is a landmark study and a first step toward the development of easy-to-perform screening tools," said Prof Fabrice André, editor-in-chief of the journal *Annals Of Oncology*. "Earlier detection of more than 50 per cent of cancers could save millions of lives every year."

In numbers

4

The amount, in centimetres, that a lifetime of heavy drinking can add to your waistline, as calculated by University College London.

2,280

The wind speed, in km/h, on the brown dwarf named 2MASS J10475385+2124234, as measured by NASA's Spitzer Space Telescope.

50

The age, in years, of a whale shark, as estimated by using radiocarbon dating on its remains. It's the oldest whale shark on record, but it's believed they can probably live for much longer.

HUMANS

Ancient human regularly climbed through the trees

Hints about locomotion found within fossil's internal structure

Just like orangutans, some species of ancient humans may have spent a lot of time climbing

Modern humans are the only primates alive today that habitually walk on two legs, and it is thought that ancient human ancestors also moved around in this way, with evidence suggesting that bipedalism emerged around seven million years ago. However, new research led by the University of Kent suggests that one hominin species that existed just two million years ago still spent a lot of its time climbing in the trees.

The research team, which included biomechanical engineers and palaeontologists, studied two fossilised leg bones found in Sterkfontein in South Africa. The fossils came from a hominin, believed to be either an early *Homo* species or *Paranthropus robustus*. The shape of the leg bone was similar to modern humans, leading to the conclusion that the species walked on two legs. But when the scientists used CT scans to peer inside the fossils, they found that the internal structure – particularly the head of the femur – suggested that the hominins had highly flexed hip joints, which was evidence that they spent a lot of time in the trees.

"It has been challenging to resolve debates regarding the degree to which climbing remained an important behaviour in our past. Evidence has been sparse, controversial and not widely accepted, and as we have shown in this study, the external shape of bones can be misleading," said Dr Matthew Skinner, who co-led the research. "Further analysis of the internal structure of other bones of the skeleton may reveal exciting findings about the evolution of other key human behaviours such as stone tool-making and tool use. Our research team is now expanding our work to look at hands, feet, knees, shoulders and the spine."

> "This could offer vital clues about when bipedalism emerged among our ancient human relatives"

THE FEMALE OF THE SPECIES
A study carried out at Claude Bernard University Lyon 1 of more than 100 species of mammals, taking in everything from bats to orcas, has found that females live longer than males in more than 60 per cent of the cases.

RENEWABLE ENERGY
Almost three-quarters of the world's power generation capacity built in 2019 uses renewable sources, a survey by the International Renewable Energy Agency has found. Renewables now make up more than one-third of the world's power sources.

Good month

Bad month

MIDNIGHT SNACKERS
Eating later in the evening could lead to us piling on the fat, a study at Vanderbilt University, Nashville, has found. The effect is thought to be due to variations in the body's metabolic rate caused by the circadian rhythm.

SUSHI LOVERS
This is a bit of a raw deal for seafood fans: fish used to make sushi contain nearly 300 times as many parasitic worms as it did 40 years ago. After poring over 123 studies spanning between 1978 and 2015, a team from the University of Washington found that the numbers of parasitic *Anisakis* worms found in fish has dramatically increased over the last four decades.

GETTY IMAGES X2, SEUNG-MIN PARK ILLUSTRATIONS: JOE WALDRON

The smart toilet (inset) can scan urine to check for diseases

TECHNOLOGY

Smart toilet checks that you're healthy

Call it the iPlop. Scientists have invented a toilet that analyses your number ones and twos to look for signs of disease.

Developed by a team at Stanford University, the device is an ordinary toilet that's been fitted with health-monitoring gadgets inside the bowl.

When you use the smart loo, your urine and stools are captured on video, which is processed by a set of algorithms. These look for anything strange, such as unusual stool consistency, urine flow rate or urine volume. Meanwhile, 'dipstick tests' in the bowl measure 10 different biomarkers in the urine. These are things such as proteins and white blood cells that can flag up certain health problems, including infection, bladder cancer and kidney failure. If the loo detects any problems, it could send an alert to the user's healthcare team, who would then be able to access the data via a secure, cloud-based system.

The toilet also includes a rather unusual means of identification. "The whole point is to provide precise, individualised health feedback, so we needed to make sure the toilet could discern between users," said team leader Dr Sanjiv Gambhir.

So the toilet uses a scanner that scans… well, we'll let Gambhir explain. "We know it seems weird, but as it turns out, your anal print is unique," said Gambhir.

Gambhir and his team have so far tested the techno-loo on 21 volunteers over the course of several months. A paper describing their research is published in *Nature Biomedical Engineering*.

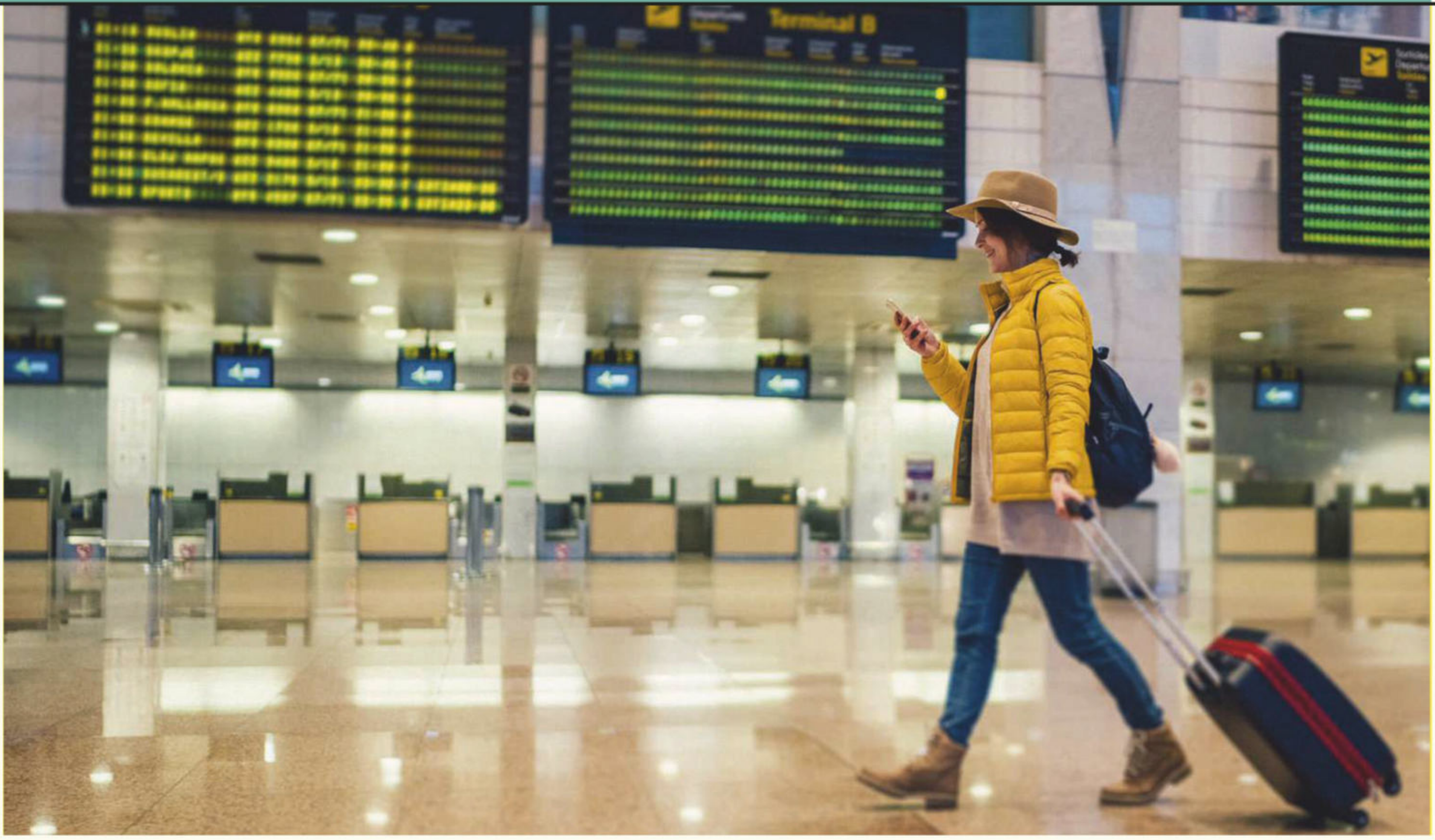
Looking forward, they're working on individualising the tests, so that someone with diabetes, say, could have their urine monitored for glucose, while someone who's genetically predisposed to bladder cancer might be monitored for blood in the urine. They also hope to develop molecular analysis for stool samples.

"That's a bit trickier, but we're working toward it," said Gambhir. "The smart toilet is the perfect way to harness a source of data that's typically ignored – and the user doesn't have to do anything differently."

GREEN PAPERS

The environmental stories you need to know

Words: **Jocelyn Timperley**



Increased air travel by the wealthy is contributing to higher energy usage

BUGGIN' OUT

Mosquitoes and other disease-carrying insects could be controlled using drugs which delete a newly discovered gene, scientists from Imperial College London have found.

The team discovered a new nutrient-sensing protein in the intestines of fruit flies. Named 'Hodor', the protein supports the regulation of food intake and development.

They found that deleting this gene in mosquitoes was fatal, providing an avenue for targeting and controlling the insects by ingestible drugs.

Only insects have this type of gene, so a drug could potentially be developed which targets carriers of malaria and other diseases but is harmless to humans, the researchers say.

CLIMATE

Climate inequality driven by transport practices

Energy footprints have been shown to grow with expenditure, and are unequally distributed – both within countries and between them

The richest 10 per cent of people consume around 20 times more energy than the bottom 10 per cent, an international study from the University of Leeds has found.

The research, which covered 86 countries, including all of Europe, looked at how different income classes tend to spend their money.

Unsurprisingly, it found that the richer people become, the more energy they tended to use. But it also showed that rich people are more likely to splash the cash on the highest carbon activities – in particular, transport.

"All over the world, the trend is that richer households spend their extra money on energy intensive goods and services related to transport," said Julia Steinberger, co-author and professor ecological economics at the University of Leeds. "This inequality and the

FINANCE FAIL

Climate finance is failing to reach the people who are most vulnerable to the impacts of climate change, a report by international charity WaterAid has found.

The report found that half of the countries receive a yearly spend of less than $5.20 per person, while some of the most vulnerable countries received even less.

"The greatest injustice is that the people who will suffer the most have done the least to cause the climate crisis," it said. "The entire continent of Africa accounts for less than 4 per cent of total global carbon emissions, but is home to 33 of the 50 countries that are most vulnerable to climate change."

overuse of transport by richer income classes was a surprise."

The disproportionally high transport energy used by rich people is due to them taking more flights, buying more and larger cars and driving longer distances in them, shows the paper, which was published in the scientific journal *Nature Energy*.

"Even within countries like Germany or the UK, richer households tend to be responsible for the kilometres driven," said Steinberger. "Not necessarily the number of trips, but the super long trips where people are crisscrossing the country with their large cars tend to be richer households."

The finding that transport, and especially flying, is the most unequal form of energy use is the most striking part of the new study, said Tim Gore, head of policy on climate, food and land rights at Oxfam. "Across the 86 countries studied, the poorest 50 per cent of people are responsible for less than 5 per cent of energy used in aviation, while the top 10 per cent richest are responsible for 75 per cent," he said.

The research could help to shed light on which climate policies are best placed to cut emissions in different areas, says Steinberger.

For example, taxing high consumption of vehicle fuel and flights could cut emissions and energy use because they are luxury products of which richer people tend to consume a lot.

"Policies that target those high consumers through monetary means and taxation make absolute sense," said Steinberger.

On the other hand, taxing home heating would make little sense for cutting emissions from energy, since heating is an essential service that everyone needs.

"The findings confirm that governments should avoid taxing energy used for essential purposes like heating homes, and instead invest public funds in retrofitting houses and buildings, as such measures are unlikely to be affordable to all," said Gore.

> **"The research could help to shed light on which climate policies are best placed to cut emissions in different areas"**

INSPIRED EXPIRED

EV WIN

Electric cars nearly always have a lower carbon footprint than petrol cars, even when the electricity powering them comes from fossil fuels, a study at Radboud University in the Netherlands has confirmed.

SOIL STORAGE

Restoring soils globally could remove up to 5.5 billion tonnes of greenhouse gases per year, a study by The Nature Conservancy in the US has found – roughly equivalent to annual greenhouse gas emissions from the US.

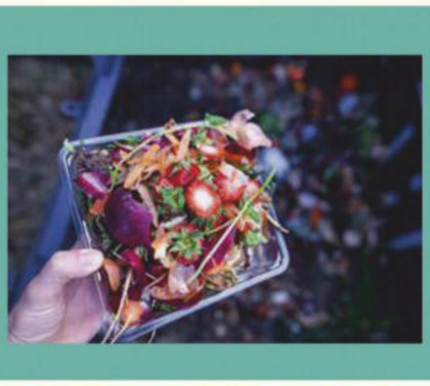
MICRO MENACE

Small amounts of microplastics may be being scattered into the environment, just from people opening plastic bags and bottles, a study at the University of Newcastle has found.

DOWN AND DROUGHT

Numbers of small annual wild plants and other delicate plant species has fallen due to the extreme heat and lack of water during the 2018 drought, a citizen survey by the National Plant Monitoring Scheme has shown.

IT'S EASY BEING GREEN



HOME COMPOST

According to the charity Waste and Resources Action Plan, the United Kingdom throws away around 9.5 million tonnes of food every year. In a landfill site, the lack of air getting to this organic waste means that it decomposes to release methane, a harmful greenhouse gas.

Home composting can cut these emissions, and even produce a nutrient-rich compost for your garden.

A year's worth of composting can save around the same amount of greenhouse gas emissions as using a kettle over the same period, England's Recycle Now campaign says.

GETTY IMAGES X5, NEWSPRESS

Prof Rebecca Saxe neuroscientist

Horizons

Social isolation triggers cravings in the brain similar to hunger

A study using fMRI scanners has found that just 10 hours of total isolation can leave the brain feeling starved

HOW DO YOU STUDY CRAVINGS, WHEN THEY ARE SO SUBJECTIVE?

A standard way is to study hunger. You have people fast for much longer than they typically would if they were hungry, then you show them pictures of the food they would like to eat, and you get a craving response in the brain.

Subjectively, people can tell you how they feel. But there is also a small, fine structure, deep in the brain, called the ‘substantia nigra’ which produces dopamine. It seems to be the best measure we have as a source of that feeling of craving. What we wanted to do in this study was to see whether that same neural circuit would be involved if you’d been isolated and given a reminder of what you were missing.

HOW DID YOU GO ABOUT IT?

Each volunteer agreed to do one day where they didn’t eat all day and one day where they didn’t see people or interact with people in any way – neither virtually nor live.

At the end of each day, we then showed them pictures of their favourite foods, and of their favourite social activities. [Using an MRI scanner], we measured brain activity in the substantia nigra to see if we could reproduce what we already expected – that there would be a bigger response to food when the volunteers were hungry, and whether that same brain region would show a response to pictures of social interaction when they had spent a day being isolated.

WHAT DID YOU FIND?

In the substantia nigra, the main area we were looking at, we found that both food cues when you’re hungry and social cues when you’re isolated evoke this basic craving response. This is incredibly interesting, that it worked in a straightforward, similar way [whether hungry for food or hungry for social interaction].

WERE YOU SURPRISED THAT THE EFFECT WAS SEEN AFTER JUST ONE DAY?

When we designed the study, one of the main things that we debated was whether 10 hours would be long enough. And also, would the volunteers still feel isolated if they knew exactly when it was going to end? We had to tell our participants what they were volunteering for, so they knew it was only a day.

We found that, for most of us, a day of isolation does produce cravings in the brain. But it affects different people to different degrees.

SURELY STUDYING SOMEONE REQUIRES SOME DEGREE OF SOCIAL INTERACTION?

A whole puzzle was how do you get a person into an MRI machine without social interaction? Normally, participating in scientific research is a very social experience. We will talk to you about what we’re doing, why

> “We found that both food cues when you’re hungry and social cues when you’re isolated evoke this craving response”

ALAMY

COVID-19 has forced many of us into isolation, but we can still enjoy interaction with loved ones through our phones

we're doing it and what you should expect. We'll then talk you through the process of getting into the MRI machine and will make sure that you're okay. Actually, figuring out how to get a person into an MRI scanner, without any social interaction, was the main challenge of the studies. We had to train the people in advance to get themselves into the scanner.

We had the minimum number of researchers involved and had them gowned and masked so that the volunteers couldn't see them or see any social interaction between them.

CAN YOUR EXPERIMENT TELL US ANYTHING ABOUT THE CURRENT SITUATION IN WHICH MANY PEOPLE ARE SELF-ISOLATING?

When we started out, we just couldn't imagine that there would be a context in which people would become isolated in this way. But now here we are in this semi-isolated state that will go on for weeks and weeks. However, the isolation that our participants experienced was much more acute. What we're experiencing [with COVID-19] is a longer term, more mixed isolation where there are some people around and we have access to all forms of media, including our phones. But for the 10 hours of isolation that our participants experienced, they didn't have any interaction from anybody at all.

ARE THERE ANY IMMEDIATE IMPLICATIONS TO THE FINDINGS?

We were inspired by a study that had done a similar thing in mice. And what we found in our study is that regions involved in craving social interaction is analogous to what our collaborators have found when they studied it in mice. That result was a key part of our original motivation, because there are research labs all over the world that use mice as the main experimental animal to test new ideas about mental health treatments, especially drug treatments. For example, studying social motivation in mice is a way people can test potential treatments for autism.

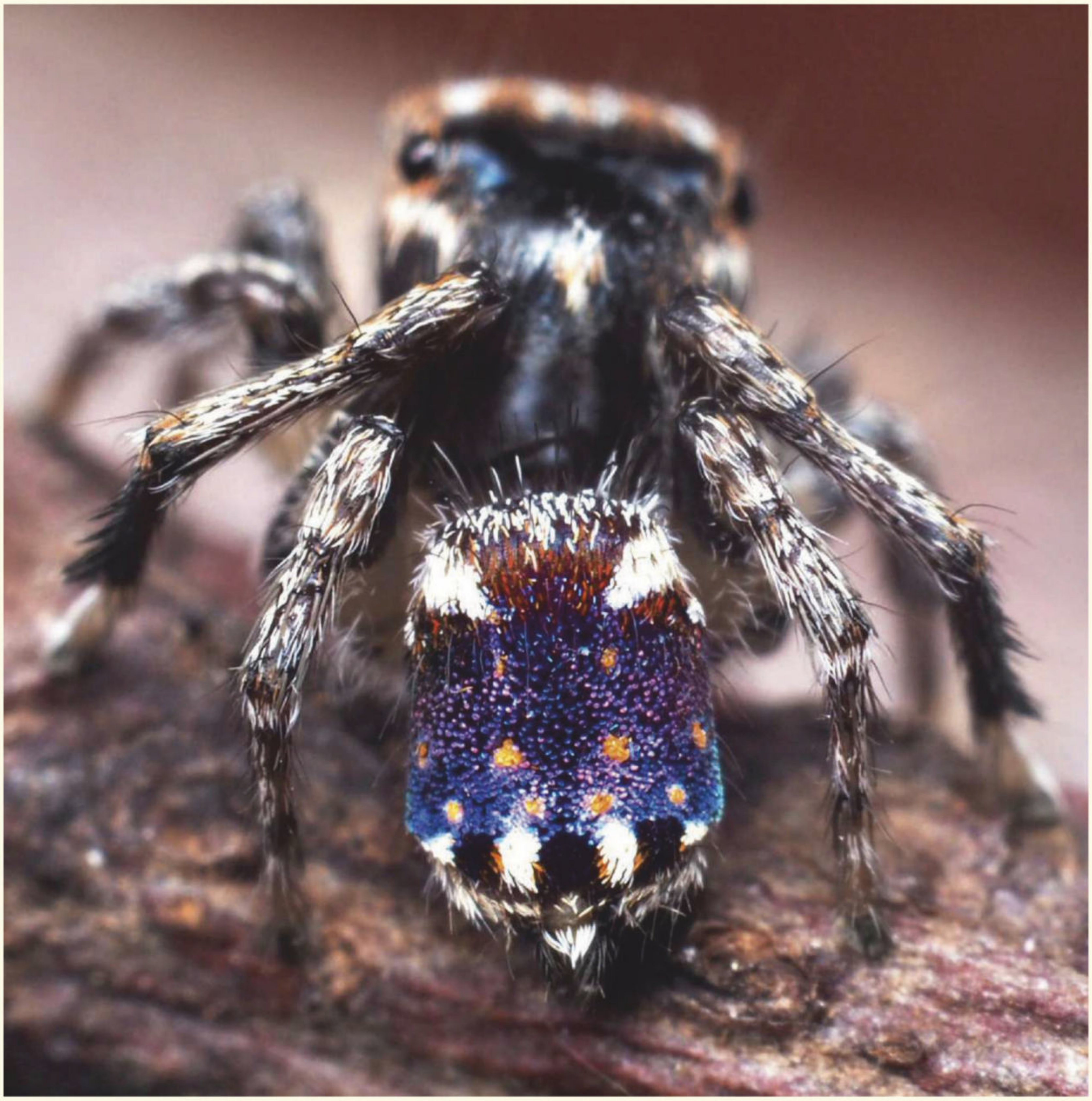
DO YOU HAVE PLANS FOR FUTURE STUDIES?

The post-doc in my lab is moving to Cambridge University this summer to follow up on the research in a bunch of ways, including looking at how social media influences experiences of isolation. She will also look at the experiences of adolescents, because despite being wildly connected on social media, adolescents actually report really high levels of loneliness.

One of the things we said in the paper, which is really important, is that although we can objectively isolate people, subjective loneliness is very different. Being alone doesn't always mean being lonely, and being connected is not always enough to fulfil your social needs. She is particularly interested in the causes and predictors of loneliness in adolescents and that's what she's going to study next year.

PROF REBECCA SAXE

Rebecca is professor of cognitive neuroscience and associate department head at the Department of Brain and Cognitive Sciences at MIT. ***Interviewed by*** **BBC Science Focus** ***commissioning editor Jason Goodyer.***



Maratus constellatus, with its iridescent blue abdomen, was found in Kalbarri, Western Australia. It's just one of the seven new peacock spiders discovered by Joseph Schubert

ZOOLOGY

Seven new species of dancing peacock spider discovered in Australia

When it comes to animals that can bust a move, peacock spiders take some beating. The mating dance of the males is truly something to behold – they flip up the display flaps found on the backs of their bodies, thrust their legs in the air, and hop around like they are living it large in Ibiza. And it's little wonder they go to such extremes: if the females are unimpressed with their efforts, there's a good chance they will kill the males and eat them.

There were previously 78 known species of the colourful spiders, which belong to the genus *Maratus*. But a glut of new finds by entomologist Joseph Schubert, who works in the entomology and arachnology department of Museums Victoria, has taken that tally up to 85. As they are not much bigger than a grain of rice, finding peacock spiders is painstaking work. To make the new discoveries, Schubert travelled all over the country, finding spiders in the states of South Australia, Western Australia and Victoria.

Like many other arachnids, peacock spiders are venomous – though they pose no threat to humans. Rather than spinning webs they silently stalk their prey, which consists of small insects such as flies and moths, before pouncing on them and making the kill.

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Face masks | Social isolation | Living naturally

REVIEW

CORONAVIRUS TRANSMISSION: SHOULD WE ALL WEAR FACE MASKS?

Several countries, such as the US, Austria and the Czech Republic, now recommend wearing face masks to stop the spread of COVID-19, but the UK government does not. Why don't all governments agree?

> **“People wear face masks because they think it’s going to protect them from the virus. But the virus isn’t floating around in the air”**

BBC *Visit the BBC’s* Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

At the time of writing, the World Health Organization (WHO) recommends that, outside of health professionals, people should only wear masks if they display symptoms of COVID-19 or are taking care of someone who does. However, more and more countries now recommend that people wear face masks in public places, and WHO is reconsidering its advice based on new evidence.

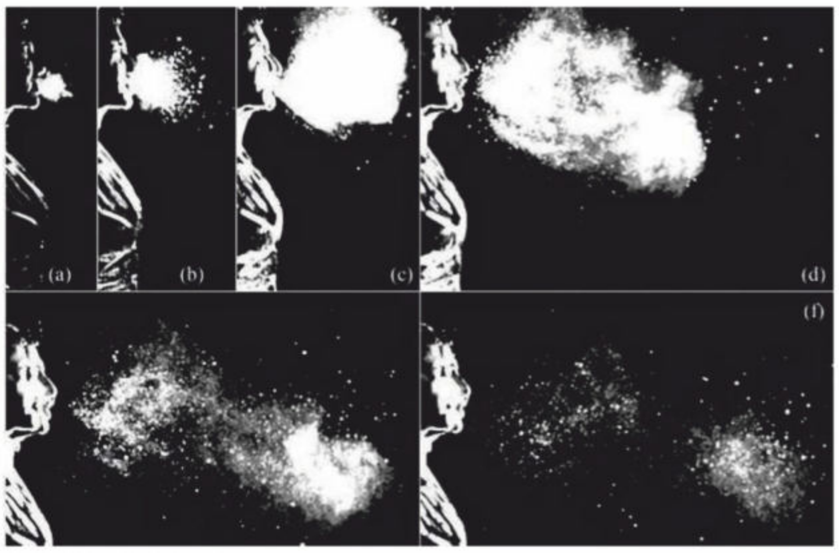
Prof Jonathan Van-Tam, England’s deputy chief medical officer and a specialist in epidemiology and pandemic preparedness, said in a briefing on 3 April: “…there is no evidence that general wearing of face masks by the public who are well affects the spread of the disease in our society. What matters right now, of course, is social distancing.”

CAN FACE MASKS STOP THE SPREAD OF COVID-19?

“The problem with the new coronavirus is that there’s too little information about exactly how it’s spread, because it’s so new,” says Dr Alexander Edwards, associate professor at the School of Pharmacy at the University of Reading. We don’t know if it’s spread more effectively through contact or coughs and sneezes, he adds.

It is not ethical to expose someone to COVID-19 to study the transmission. Instead, biologists have to make do with other methods. One study from MIT used high-speed cameras to track the droplets expelled in coughs and sneezes. They found that puffs of air carry droplets for up to six or eight metres, for coughs and sneezes respectively. Another study, conducted by aerosol specialist Dr Boris Gorbunov, found that taking wind conditions into account could bring the distance a cough travels up to 25 metres.

Researchers at Hong Kong University and the University of Maryland took another approach. For a study published in the journal *Nature Medicine* in April, they looked at patients with other types of coronaviruses, along with influenza and rhinoviruses. The researchers collected droplets from the patients’ breath with and without a surgical face mask and counted how many copies of the virus were present. Three out of 10 coronavirus patients had a detectable viral load in their breath without a face mask, compared to none when wearing one.



A study by MIT tracked the droplets expelled in coughs and sneezes and found that they could travel for six to eight metres

“It makes perfect sense that if you wear a mask over your face, when you cough, you might expect that the mask would reduce the spread of that cough,” Edwards says. “We don’t actually know how much that reduces it, but the idea of a face mask is a good one.”

WHY AREN’T WE BEING ADVISED TO WEAR FACE MASKS?

“One of the reasons that people wear masks is they think that it’s going to protect them from the virus. But the virus isn’t floating around in the air,” Dr Shunmay Yeung of the London School of Hygiene and Tropical Medicine told the BBC. “It’s probably going to be on my hand because of shaking hands with someone who’s got the virus, and I have transmitted it. I have carried the virus to my face.”

Simply wearing a mask won’t eliminate your risk of catching or spreading the virus. “Remember that some face masks are designed, when you breathe out, to let the air go out as normal, and they only filter the air when you breathe in,” Edwards says. “And a face mask is only as good as it fits.”

A face mask may reduce your risk, but it’s vital that people don’t become complacent because they think they’re protected by a mask. Even the best mask can’t replace social distancing and good hygiene.

SO, SHOULD WE BE WEARING FACE MASKS?

“I don’t think it’s a bad idea, so long as people understand that they are not magic shields,” Edwards says. If you do wear one, Edwards suggests you keep yourself and those around you safe by behaving as though it doesn’t work.

Finally, ensure you’re not depriving anyone, like health professionals, of the personal protective equipment they need. And importantly, if you have symptoms, don’t go out!

by **SARA RIGBY**

Sara is the online assistant at BBC Science Focus.

ALAMY, MITW

ANALYSIS

SOCIAL ISOLATION: WHAT DOES IT DO TO OUR BRAINS?

The country-wide lockdown is vital for slowing the spread of COVID-19. But why is it so tough for us to stay at home and what are the consequences?

Stay at home. Don't visit friends and family, and don't have them visit you. Keep clear of strangers. These don't sound like particularly challenging instructions. Except, if you look at the news, at social media, or even out of the window at times, it's clear that a lot of people are struggling with the whole 'social isolation' thing. Why? What could be difficult about not going to work and not engaging with others?

As it happens, everything. We humans are an incredibly social species, arguably more so than any other on Earth. Our brains have evolved for socialisation in a variety of different ways, which means this social isolation instruction is a pretty big ask, with a number of consequences.

OUR BRAINS HAVE EVOLVED FOR SOCIALISATION

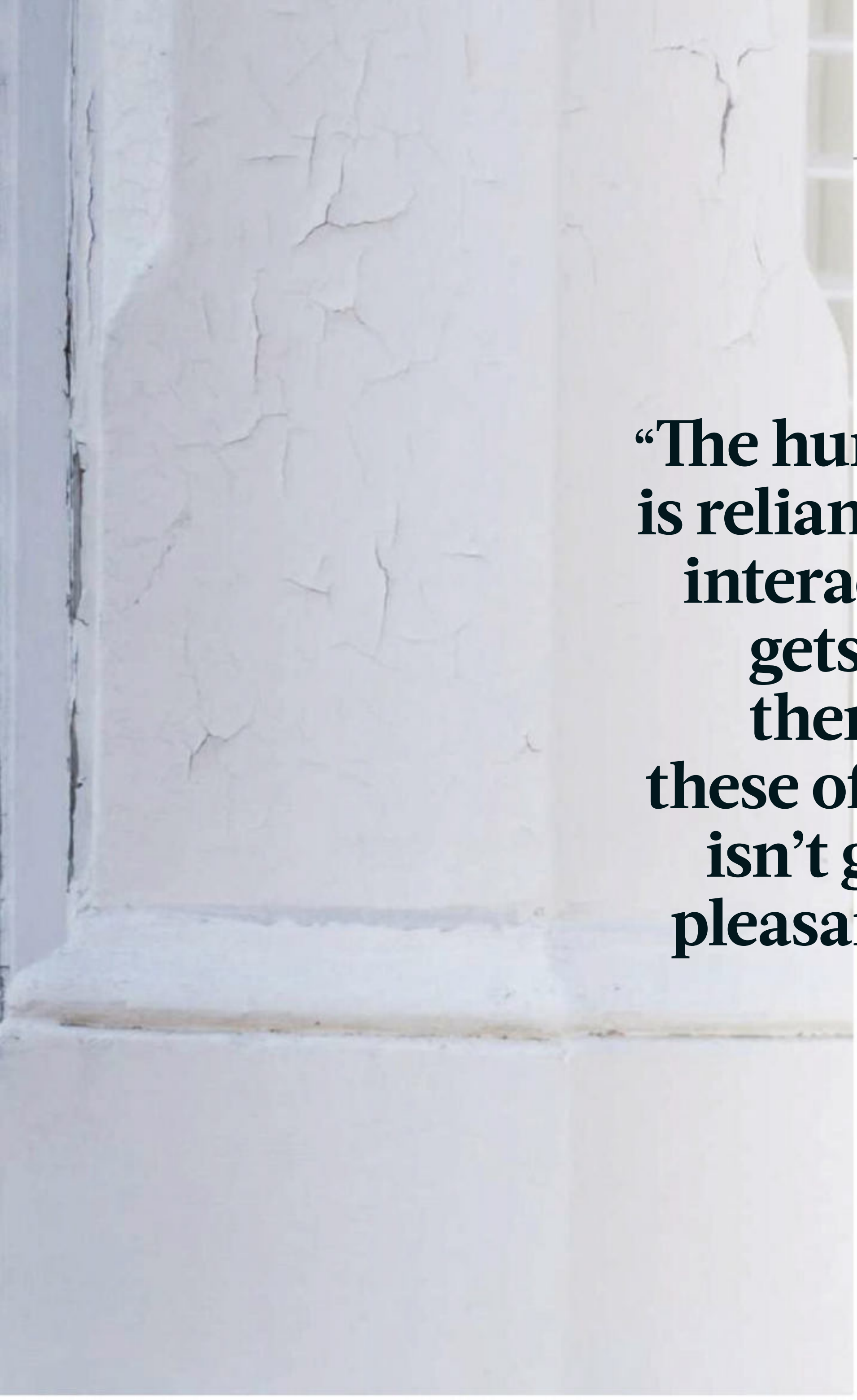
Why do humans have such big, smart, resource-hungry brains at all? There are a lot of theories around this, but one of the more prominent ideas is the 'ecological dominance-social competition model'. This argues that early human tribes were so communal, so cooperative, so successful that they neutralised all the natural factors that usually drive evolution. Predators? Finding food? Or mates? When you were born into a human tribe, none of these things were an issue, others took care of it, so they weren't a threat to your survival, so 'traditional' natural selection is disrupted.

What did determine an individual's chances of success was how well we performed within the tribe. How good you were at forming relationships, cooperating, communicating, influencing, even deceiving; these were the things that dictated human success now. These things required greater intelligence. Running from a predator requires physical skill. But keeping track of all your friendships, your commitments, your debts and responsibilities, in a group of individuals all as smart as you? That requires cognitive processing power. And thus, the human brain increased dramatically in size and power, particularly over the last two million years.

That's one theory. Not everyone agrees with it. But it's hard to dispute that a lot of parts of the brain seem to exist largely to facilitate social bonding and communication.

The chemical oxytocin, aka 'the cuddle hormone', has a range of functions in the brain that enhance interpersonal bonds. We have a part of the visual cortex, the fusiform gyrus, dedicated to detecting and reading faces. Other parts of the brain, like the anterior insular cortex, are responsible for empathy, the ability to detect someone's emotional state and experience it ourselves. There are even emotions themselves, like embarrassment and guilt, that only make sense when you take other people's reactions and viewpoints into account.

Our brains are clearly social in nature. Depriving them of social contact may be fundamentally unsettling. For example, studies have found that even the most fleeting social interaction can cause the brain to experience low-level pleasure. And while most other social species bond via grooming, prominent



ABOVE When the UK went into lockdown, people started to put rainbow pictures in their windows as a message of hope and solidarity

ALAMY

> “The human brain is reliant on social interactions and gets a lot from them. Cutting these off abruptly isn’t going to be pleasant or easy”

anthropologists suggest that the human equivalent is gossiping, and that may even be a big factor in why we evolved language in the first place; it would take hours each day to groom everyone in a large human tribe, but you can say nice things to all of them at once.

Psychologists have deemed solitary confinement to be a literal form of torture. As stated, the human brain has seemingly evolved for socialisation. So, denying it social contact is depriving it of something it deems vital. Indeed, studies have revealed that a socially isolated person shows brain activity that’s very similar to literal hunger, even after a mere 10 hours of no social contact (see p26).

Studies like these show that the human brain is reliant on social interactions and gets a lot from them. Cutting these off abruptly isn’t going to be pleasant or easy, so it’s no wonder people are finding it difficult.

‘I WON’T GO OUT’ VS ‘YOU CAN’T GO OUT’

It’s not that the human brain needs constant, never-ending socialisation. Much as we enjoy it, social interactions do still take time, energy and effort, and the brain can’t sustain this indefinitely. That’s why, as social as we are, research suggests we still need privacy as well, in a fundamental way.

Now, we’ve arguably got more privacy than we could ever want. And nobody seems happy about it, with countless people chomping at the bit to mingle, or live streaming their every waking moment to anyone who’ll listen.

A lot of this can be attributed to a sense of autonomy. One thing the human brain finds typically reassuring and rewarding is a sense of control, the ability to make decisions and determine one’s own actions and situations. That’s why there’s a big difference between choosing to stay at home, and being told to stay home.

It’s a well-known human phenomenon, that of ‘reactance’, which is where when humans are told they can’t have or do something, they’re instinctively motivated to want it more. We’re a contrary lot, but it does mean that being told we can’t socialise will directly lead to an increased desire to do so. And that desire was already pretty strong.

IS SOCIALISING ONLINE AN ACCEPTABLE SUBSTITUTE?

Can social media and video-streaming software fill the gap, or satisfy the craving, that results from a loss of physical social contact? People have been using them in interesting and creative ways, admittedly. But is it enough? That’s harder to say.

So much of human communication and interaction is non-verbal, relying on body language, eye contact, expressions, tone of voice, and so on. How many of these are conveyed by remote communication? Not all of them, undoubtedly.

And the human brain is extremely quick and sensitive to even minor discrepancies in communication. We’re good at recognising a fake smile or laugh, and when something is very close to the human norm, but not quite right in terms of all the subtle cues and traits, it tends to freak us out, hence the ‘uncanny valley’ effect that’s seen in human-like robots.

But even if social media and other forms of remote communication aren’t giving our brain everything they’re used to, it’s still surely better than nothing. They’re likely to be staving off the more tangible problems of social isolation, and surely that’s no bad thing.

by **DR DEAN BURNETT**

Dean is a neuroscientist and author. His latest books Why Your Parents Are Driving You Up The Wall And What To Do About It *and* Psycho-Logical *are perfect lockdown material for those experiencing stress and frustration.*

DISCOVER MORE

WHO advice for protecting yourself and others
bit.ly/WHO_health_tips

COMMENT

THE CORONAVIRUS PANDEMIC: IS NATURE ‘SENDING US A MESSAGE’?

Experts and celebrities alike have suggested that this new coronavirus outbreak is a form of punishment from the planet, inspiring the ‘humans are the virus’ meme online. But can the idea that natural means better and everything else is harmful have troubling consequences?

Chinese wet markets offer meat in its natural state: unrefrigerated, unprocessed, unpackaged, uncooked and sometimes unslaughtered. When I lived in China, wandering through the open-air stalls felt liberating and authentic, a welcome change from sterile supermarkets where the chicken lies behind glass, plastic-wrapped by faceless corporations.

Similarly, Chinese medicine represents a natural alternative to the pills pushed by Big Pharma. Gnarled roots, ground herbs, wizened mushrooms, and exotic animal parts line the traditional pharmacy’s walls. These claim to be Mother Nature’s cures that will realign us with her rhythms, unlike the synthetic chemicals that, according to some, will end up making society sicker.

Now, of course, we are reckoning with the catastrophic shortcomings of unregulated open-air wet markets. Calls for change within China will hopefully lead to safer food standards and reduced exotic animal trade. But beyond reforms of specific practices, there is a broader lesson to be learned, one that humans persistently ignore: natural does not necessarily mean better.

Clearly we have some way to go, since responses to the pandemic have framed it as a ‘punishment from nature’ for our unnatural lifestyle.

> “The urgency of living in harmony with nature has never been more acute. But we should not make the mistake of believing that living in harmony with nature requires living naturally”

Circulating on social media is the idea that ‘humans are the virus’, yet the arguments towards this are suspiciously general, theological catch-alls: they take every human sin, and discover that all of them contribute to the current crisis.

Is industrial agriculture one’s focus? Then it is to blame for the coronavirus. Likewise for overconsumption and climate change. The ultimate version of this approach, now a viral meme on social nature, is simply to blame humans for all disharmony in nature. The virus isn’t the problem, since viruses can’t sin. They are a part of nature – perfect and harmonious unless humans interfere. We, the sinners, are the virus.

MIXED MESSAGES

“Nature is sending us a message,” said Inger Andersen, executive director of the UN Environment Programme. Or, as the Duchess of York tweeted: “Mother Nature has sent us to our rooms… like the spoilt children we are. She gave us time and she gave us warnings. She was so patient with us. She gave us fire and floods, she tried to warn us but in the end she took back control.”

Though ‘nature’ may look like a secular term, this framing is fundamentally a religious one. Religious leaders throughout history have framed natural disasters as God’s punishment – even today, prominent figures blame coronavirus on ‘unnatural’ sexuality, just as they did with everything from hurricanes to HIV. In this view, God is synonymous with nature, and ‘natural’ means whatever has been ordered by

GETTY IMAGES

China's markets sell meat and live wild animals. This may be considered a more 'natural' way of shopping for meat, but it isn't necessarily better, as lax food safety and hygiene – along with poor animal welfare – can lead to outbreaks of disease, like COVID-19

God. The opposite of natural is anything chosen by humans that does not align with the divine order – and it leads inevitably to suffering.

Understandably we want to believe natural forces are benevolent. That's why studies show we tend to overestimate the risk of actions perceived as tampering with nature, from nuclear power plants to lab-grown meat. We know what happened when Dr Frankenstein tampered with nature, or, as it's often put, when he 'played God'.

NATURE VS NATURAL

The urgency of living in harmony with nature has never been more acute. But we should not make the mistake of believing that living in harmony with nature requires living naturally. After all, the technology required for renewable energy is far less natural than simply burning wood. Refrigeration and freezing prevent spoilage and food waste.

Humans are, as the author HG Wells put it, unnatural animals. Our success in saving infants and the elderly contradicts nature's intentions, and few would deny the morality of our unnatural efforts. And yet, given the susceptibility of the elderly to COVID-19, the narrative of nature's punishment makes for a ghastly conclusion about whether we should continue with our successes.

Nature is not a benevolent deity with 'intentions', and natural is not a synonym for holy. Understood as an absence of human intervention, naturalness is neither good nor evil. Now more than ever, understanding the difference is crucial for the health of humanity, and the planet. The time has come to abandon our false faith in natural goodness and confront the complexity of what it means to be responsible unnatural animals in a natural world. **SF**

by **PROF ALAN LEVINOWITZ**

Alan is a scholar of religion. He teaches at James Madison University and has written for Wired, Vox *and the* Washington Post. *His new book,* Natural: How Faith in Nature's Goodness Leads to Harmful Fads, Unjust Laws, And Flawed Science *(£20 Profile Books) is available now.*

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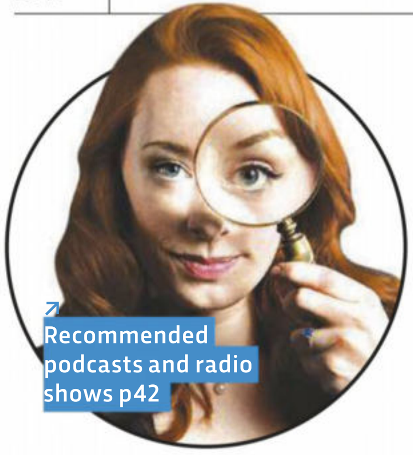

↗ Recommended podcasts and radio shows p42

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

NEWS

Formula 1 teams race to build ventilators

Engineers from aerospace, consumer tech and motorsport have answered the government's plea

In mid-March 2020, just a few days after COVID-19 had been declared a pandemic by the World Health Organization, the UK government put out a plea to businesses to help make ventilators and components. To aid any companies wanting to help, the government produced a list of guidelines for designing Rapidly Manufactured Ventilator Systems (RMVS). There was a huge response, with some of the biggest names in aerospace, technology and engineering stepping up to the plate.

At the time, the UK only had some 8,000 ventilators, and the government thought that an additional 30,000 machines, made as quickly as possible, should allow the NHS to deal with the enormous increase in respiratory patients arriving at hospital with COVID-19.

One consortium, VentilatorChallengeUK, which includes Airbus, McLaren, Mercedes, Ford and Rolls-Royce along with other household names, is working on two ventilators: one is based on the Penlon ESO2, which is the clinicians' first choice for the RMVS; and a scaled-up version of an approved existing ventilator, the Smiths paraPAC, commonly used in ambulances. These machines can be assembled from materials and parts already available in the UK supply chain. In mid-April, the Penlon ventilator received regulatory approval and the government placed an order for 15,000 of the devices, making it the first new British ventilator to receive the go-ahead.

While Penlon and Smiths can usually create 50 to 60 ventilators per week, with the help of the consortium, they are hoping this can be boosted to 1,500 a week by early May. "Ventilators are intricate and highly complex pieces of medical equipment and it is vital that we balance the twin imperatives of speed of delivery with the absolute adherence to regulatory standards that is needed to ensure patient safety," warns VentilatorChallengeUK chairman Dick Elsy.

Elsewhere, the billionaire inventor James Dyson, who is best known for his space-age vacuum cleaners, announced that he had designed a new battery-operated ventilator from scratch. The government has put in an order for 10,000 of these CoVent devices. ►

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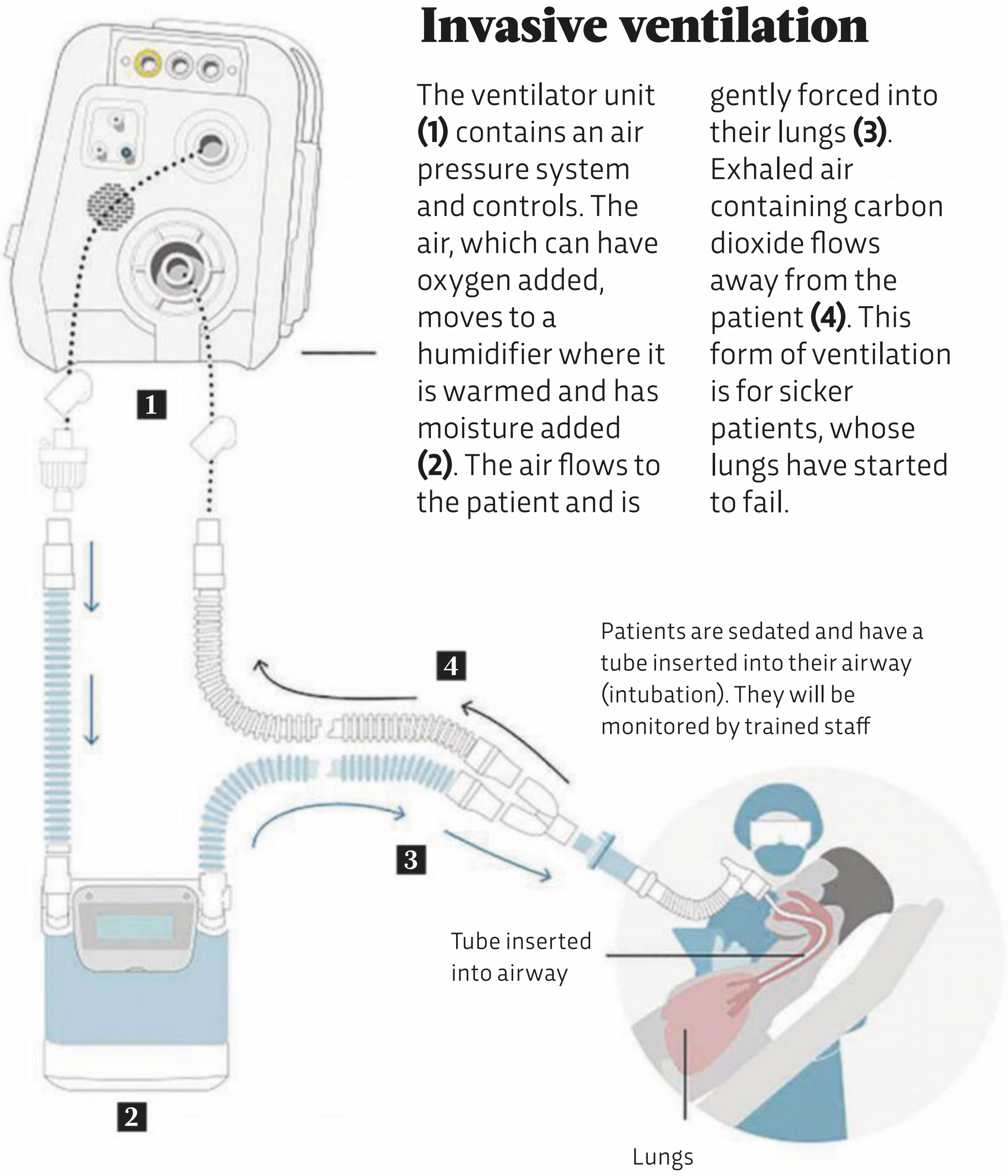
HOW IT WORKS

Ventilators

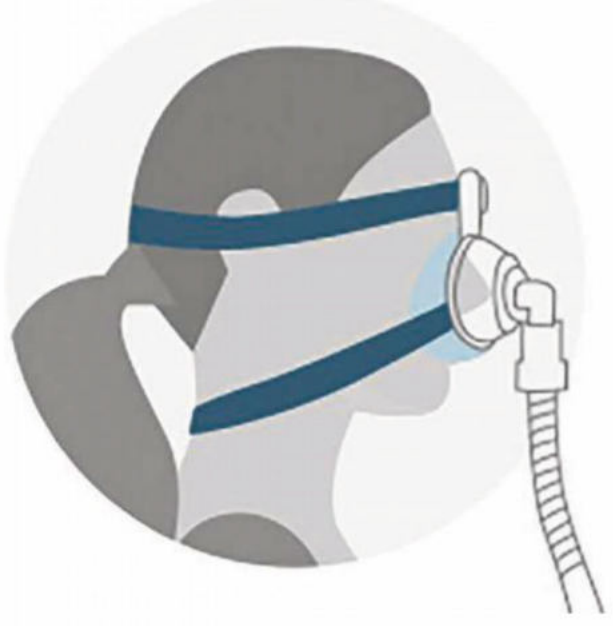
Invasive ventilation



The ventilator unit **(1)** contains an air pressure system and controls. The air, which can have oxygen added, moves to a humidifier where it is warmed and has moisture added **(2)**. The air flows to the patient and is gently forced into their lungs **(3)**. Exhaled air containing carbon dioxide flows away from the patient **(4)**. This form of ventilation is for sicker patients, whose lungs have started to fail.

Patients are sedated and have a tube inserted into their airway (intubation). They will be monitored by trained staff

Non-invasive ventilation



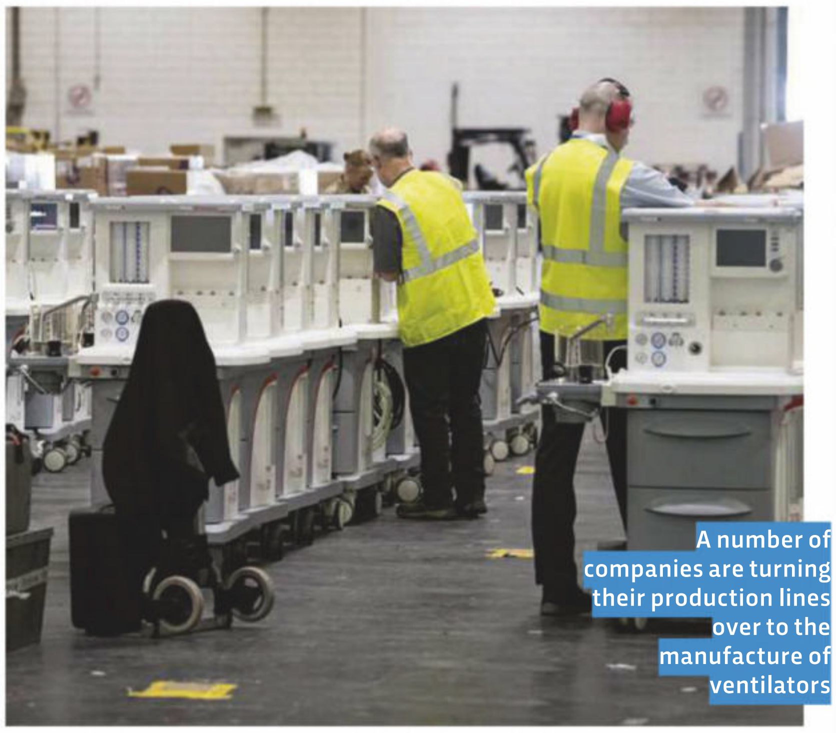
With this form of ventilation, no sedation or intubation is required. A mask is fitted over the nose and mouth to deliver air – potentially with added oxygen – to the patient. This is the preferred method for patients who are experiencing milder symptoms.

> “Devices from Dyson, Babcock and Sagentia are subject to regulatory approval and there’s no guarantee that will be granted”

Defence company Babcock also said it would be making 10,000 machines, which it developed along with an international supplier of critical care ventilators. Meanwhile, Sagentia, a Cambridge-based science, technology and product development company, has designed 20 trial devices that minimise sourced components. The government has put in an order for 10,000 of these machines too.

But the issue is, the devices from Dyson, Babcock and Sagentia are subject to regulatory approval and there’s no guarantee that will be granted. And there are questions raised about whether any of the companies involved could manufacture thousands of machines in time for the virus’s peak. The government has already cancelled its order for one ventilator, called Project BlueSky, as it did not meet requirements.

The health secretary Matt Hancock has since revised the 30,000 number down to 18,000. With 8,000 ventilators due to arrive from overseas, hopefully there will be sufficient machines available to deal with the crisis. But we are treading new ground here, and if there are further peaks in the pandemic, then it is essential that the NHS has the equipment it needs to keep the UK safe.

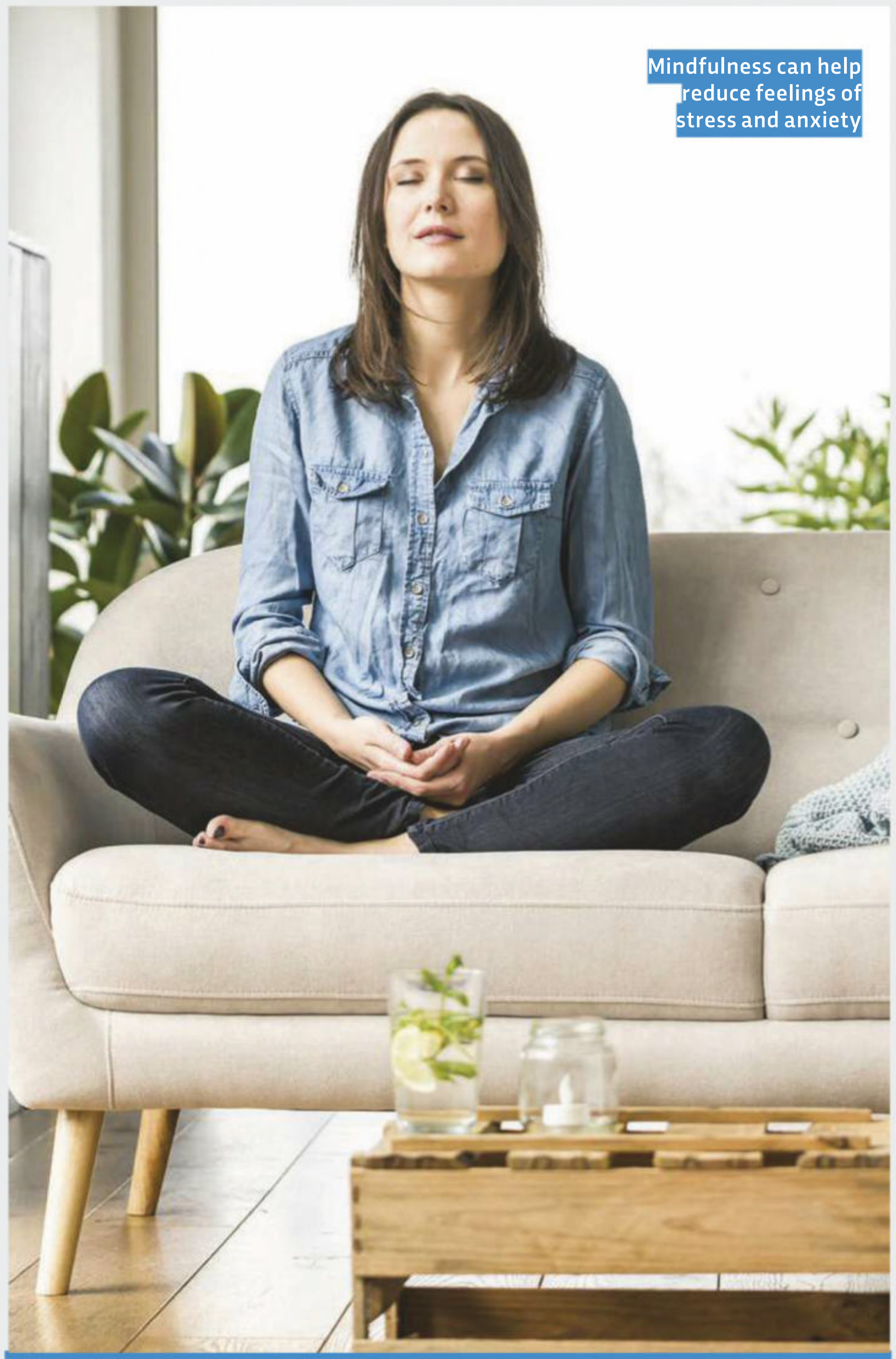


A number of companies are turning their production lines over to the manufacture of ventilators

What is mindfulness meditation?

All of the apps highlighted here have one feature in common: mindfulness meditation. Mindfulness-based therapies have been shown to reduce anxiety and stress, and prevent relapses of depression.

Mindfulness meditation involves closing the eyes and allowing thoughts to come and go. It often involves focusing attention on the breath, or on the body. Contrary to popular belief, it’s *not* about trying to get rid of unwanted thoughts: the aim is rather to let thoughts pass through the mind, without latching onto them.



Mindfulness can help reduce feelings of stress and anxiety

NOTE: These apps are not intended as a replacement for professional medical advice. If you feel like you’re struggling with your mental health, contact your GP. You can also find tips for coping with the coronavirus outbreak at **nhs.uk/oneyou/every-mind-matters/**

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ON TEST

5 mental health apps to help you through the coronavirus crisis

In late March, as UK lockdown was just beginning, surveys in the UK and the US were already showing that the pandemic was negatively affecting people's wellbeing. Thankfully, there are resources out there to help us. Mental health apps can provide one way to calm the mind and help you keep track of wellbeing. Here are five of our favourites, all available on iOS and Android.

Words: James Lloyd

1. CALM

Calm places mindfulness front and centre, and is the place to go for pure relaxation. Open the app and you're greeted by the sound of lapping waves. There's a 10-minute 'Daily Calm' meditation, plus an archive of themed mindfulness lessons, expert masterclasses and mindful stretches for the body. *Calm*'s other main focus is sleep, with a library of bedtime stories for grown-ups, many of them narrated by celebrities (fall asleep to Matthew McConaughey's Texan drawl), plus a selection of sleep music featuring Moby, Sam Smith and Sigur Rós. A lot of this app's content is paywalled, however, so you're best off upgrading for the full experience.

Free to download. Full access: £13.49/month, £35.99/year

Best for: relaxation

2. HEADSPACE

Co-founded and voiced by former Buddhist monk Andy Puddicombe, *Headspace* – like *Calm* – is centred on mindfulness and sleep. It sports a more interesting art style, though, with playful illustrations and animations. The meditation library is especially rich, with courses on everything from self-esteem and anger to creativity and pregnancy. The sleep section, meanwhile, features pre-sleep wind-downs, quirky bedtime stories, an eight-hour-long 'sleep radio', and 'SOS exercises' for when you wake up in the night. You'll get the most out of the app if you pay, but there's a free 'Weathering the storm' package available during the pandemic.

Free to download. Full access: £9.99/month, £49.99/year

Best for: mindfulness

3. MOODPATH

Developed in collaboration with psychologists, *Moodpath* is aimed at those who think they might be experiencing symptoms of depression. The app asks three simple questions three times a day about the user's wellbeing. After 14 days, it gives an evaluation and recommendation of action, which can then be passed on to a therapist or doctor. Alongside this free assessment, the app also has a library of guided meditations and wellbeing courses. Most of these are paywalled, but there are free courses on depression, mindfulness and the coronavirus pandemic, with helpful tips on how to stay mentally healthy.

Free to download. Full access: £24.99/quarter

Best for: monitoring depression

4. SANVELLO

This is one of the most comprehensive mental health apps out there, and it's offering free access to everyone during the coronavirus crisis. In addition to its meditations (which come with a neat option to change the background soundscape), *Sanvello* features self-care courses based on the principles of mindfulness and cognitive behavioural therapy (CBT), along with oodles of ways to record thoughts and goals. What's especially helpful is that you can keep track of your healthy (or not-so-healthy) habits such as exercise, sleep and caffeine intake, and then plot them against mood to visualise how they might be affecting your mental health.

Currently free.

Best for: tracking wellbeing

5. HAPPIFY

Happify offers a more gamified approach to wellbeing, focusing on six skills, including gratitude, empathy and healthy living, with interactive activities for each one. Some of the activities are games (one involves destroying negative thoughts by firing projectiles at them, *Angry Birds* style), and some are exercises led by the app's AI assistant, Anna.
It might be a little gimmicky for some, but one particularly nice touch is that all of the activities come with a 'Why it works' section that references scientific studies.
Another plus point is that the free version provides access to plenty of content.

Free to download. Full access: £13.49/month, £124.99/year

Best for: interactivity

Ideas we like... on lockdown

Okay, we're all stuck inside, which means we can't go to the cinema or plan a trip to a museum at the drop of a hat. But there's still plenty of science-y stuff to enjoy from the comfort of our homes

Put on a science show

When things are getting a bit much, stick on an hour of science TV. The BBC is busy putting its rich library of educational series back up on iPlayer. There's Brian Cox's brilliant series *The Planets* for those who need a little help bringing the Solar System to life, and *Earth From Space* for those who need something soothing. And if all else fails, there are plenty of boxsets of old David Attenborough shows available now.

Meanwhile, over on BBC Sounds, there's a huge array of some of our favourite podcasts and radio series, including over 200 episodes of *The Life Scientific* with Prof Jim Al-Khalili and a wide range of expert guests. You could also listen to any of the 15 seasons of the brilliant *The Curious Cases Of Rutherford & Fry*. For a touch of lighter listening, Sir David Attenborough reads *The Peregrine*, the British nature-writing classic by JA Baker.

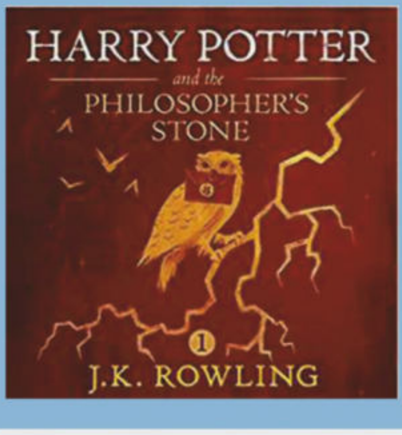
bbc.co.uk/iplayer ; **bbc.co.uk/sounds**

Let Dr Hannah Fry and Dr Adam Rutherford bring a dose of science to your radio

Enjoy a free audiobook

As the schools shut in the UK, Amazon announced it would make over 300 audiobooks free on Audible for as long as the lockdown lasts. For when you want to keep the homeschooling going, there are literary classics on offer, like *Frankenstein* and *Brave New World*. But when you just need some peace and quiet, or a bedtime story, there are old favourites like *Harry Potter* and *Rastamouse*. There are even books available in multiple languages – that's the French lessons sorted.

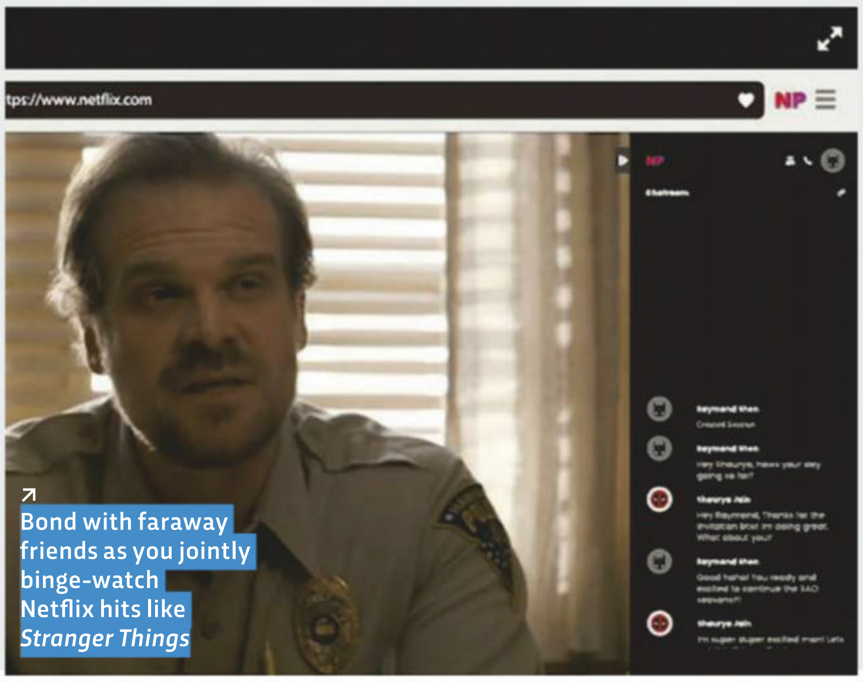
stories.audible.com



Stream TV together

Now that we've all run out of DIY to do, it's time to relax. Netflix Party lets you watch TV shows with friends and family in distant places. It doesn't sound like much, but it could make a difference to someone you know who's living on their own. It's only available on the Google Chrome browser – you need to use your home computer to stream – but the app lets you sync your streams so you can enjoy shows at the same time.

netflixparty.com

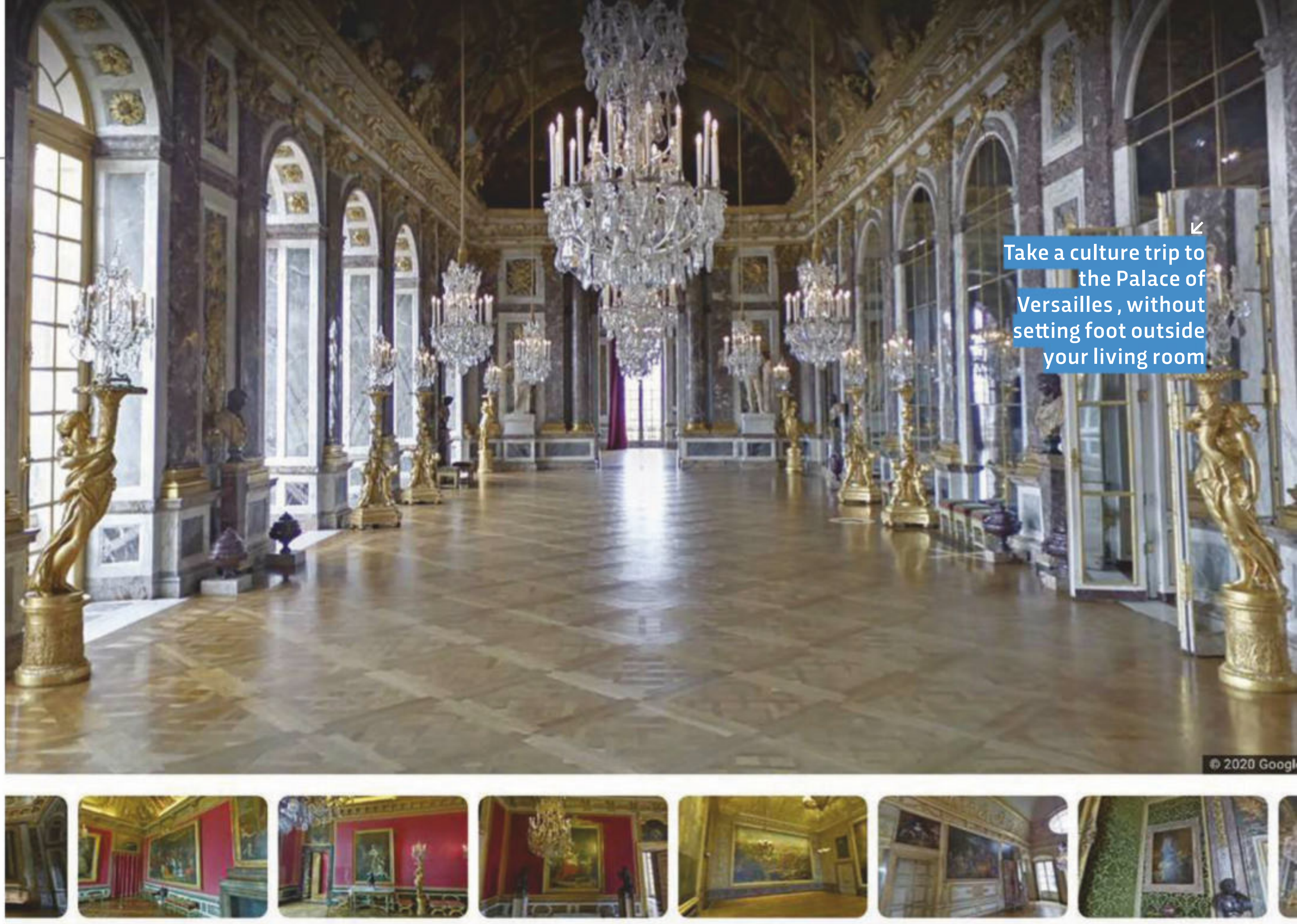


Bond with faraway friends as you jointly binge-watch Netflix hits like *Stranger Things*

Visit the zoo

Why not take the kids on a virtual day out to the zoo? Many zoos have turned to sharing the lives of their animals online; Chester Zoo, for example, runs a live virtual zoo day every Friday on their Facebook page and you can catch up with previous days on YouTube. Meanwhile, Edinburgh Zoo is streaming live footage of their animals, including the giant panda Yang Guang, and the Sumatran tiger Dharma.

chesterzoo.org/virtual-zoo/
edinburghzoo.org.uk/webcams/


Take a culture trip to the Palace of Versailles , without setting foot outside your living room

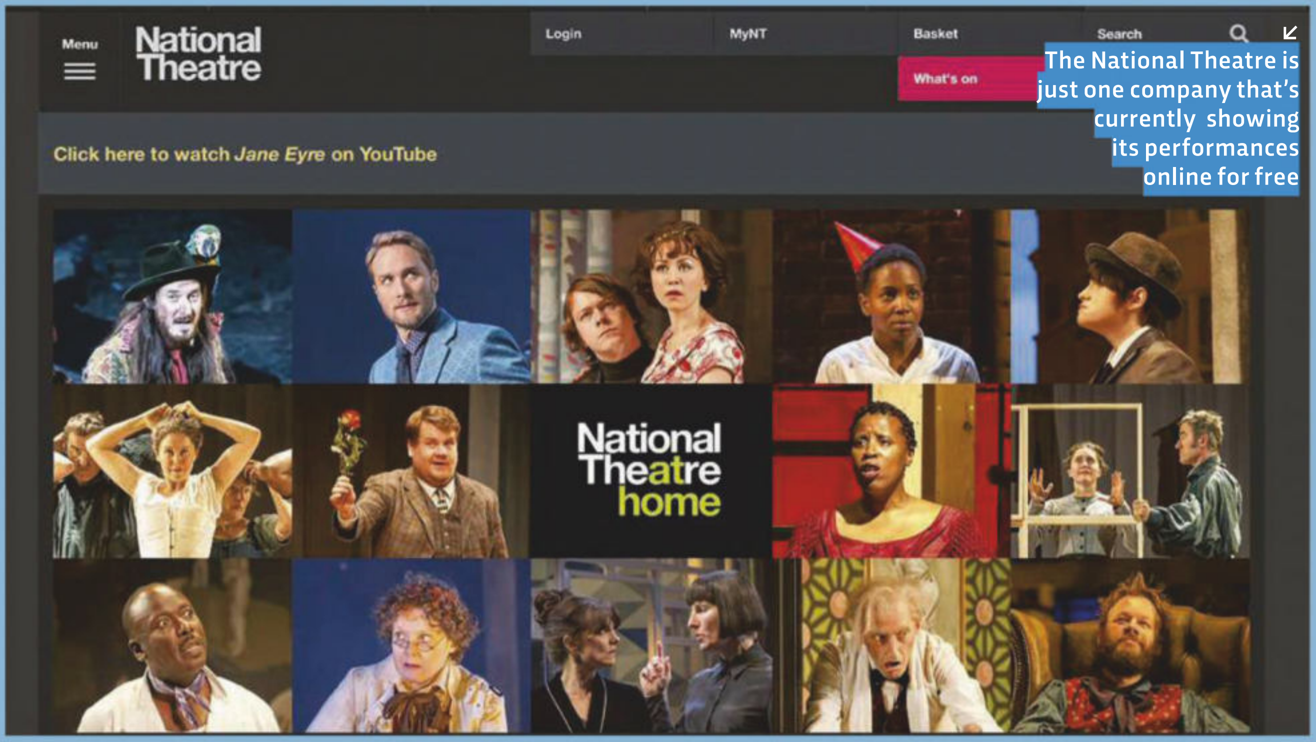
Tour a museum

It has never been easier (or cheaper) to explore some of the world's finest art galleries and museums. Through Google's *Arts & Culture* app, places like The Museum of Modern Art in the US, and the Palace of Versailles in France have made themselves virtually available. Just download the app on your phone or tablet, or visit their website via your computer.

To make the most of *Arts & Culture*, try it with a VR viewer – be it a high-tech Oculus or a Google Cardboard.

Many people who normally work in museums, science centres or research labs have taken to using Twitter as a new method of communicating their work. Check out the #ScienceFromHome and #MuseumFromHome hashtags for short culture bursts.

artsandculture.google.com



The National Theatre is just one company that's currently showing its performances online for free

GETTY IMAGES, BBC, CHESTER ZOO

Take in a performance

In March, the World Health Organization (WHO) launched the Together, At Home campaign with activism group Global Citizen, which has since seen 30-minute Instagram Live sessions from artists such as John Legend, Niall Horan and Coldplay's Chris Martin,

Then on 18 April, WHO, Global Citizen and Lady Gaga curated an eight-hour entertainment special to celebrate the efforts of community health workers around the world. *One World: Together At Home* globally broadcasted sets from Andrea Bocelli, Elton John, Stevie Wonder, and many more.

It was hosted by American talk show personalities Jimmy Fallon, Jimmy Kimmel and Stephen Colbert, and televised in the UK on BBC One. If you missed it, you can watch the concert on BBC iPlayer.

Meanwhile, Andrew Lloyd Webber announced a new YouTube channel, The Shows Must Go On!, to bring theatre to the public in the time of social isolation. Streaming every Friday, one of Webber's musicals will be available to watch online for the 48 hours following. Elsewhere, over on the National Theatre YouTube page, plays are being streamed for free each Thursday, at 7pm in the UK. You can watch these, on demand, for a week after their stream. For ballet and opera, the Royal Opera House is releasing performances weekly on their social media channels.

globalcitizen.org/en/connect/togetherathome/

LIFE FINDS A WAY

WE HUMANS TRANSFORM LANDSCAPES AND LEAVE OUR UNMISTAKABLE MARKS ON THE WORLD. BUT THESE MARKS ARE NOT ALWAYS INDELIBLE, BECAUSE WHEN WE MOVE OUT, NATURE QUICKLY MOVES IN TO STAKE ITS CLAIM ONCE MORE

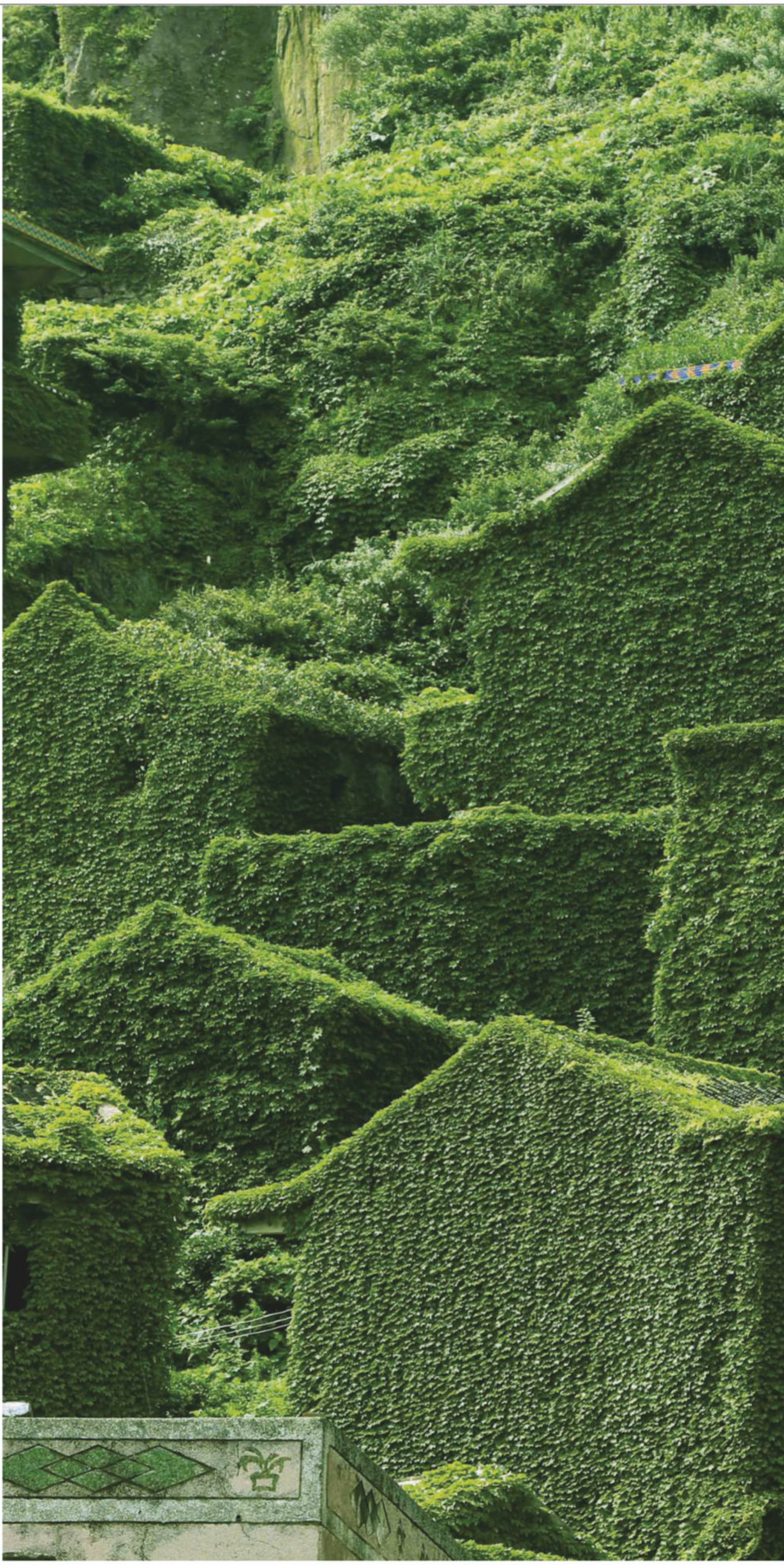
WORDS: HAYLEY BENNETT

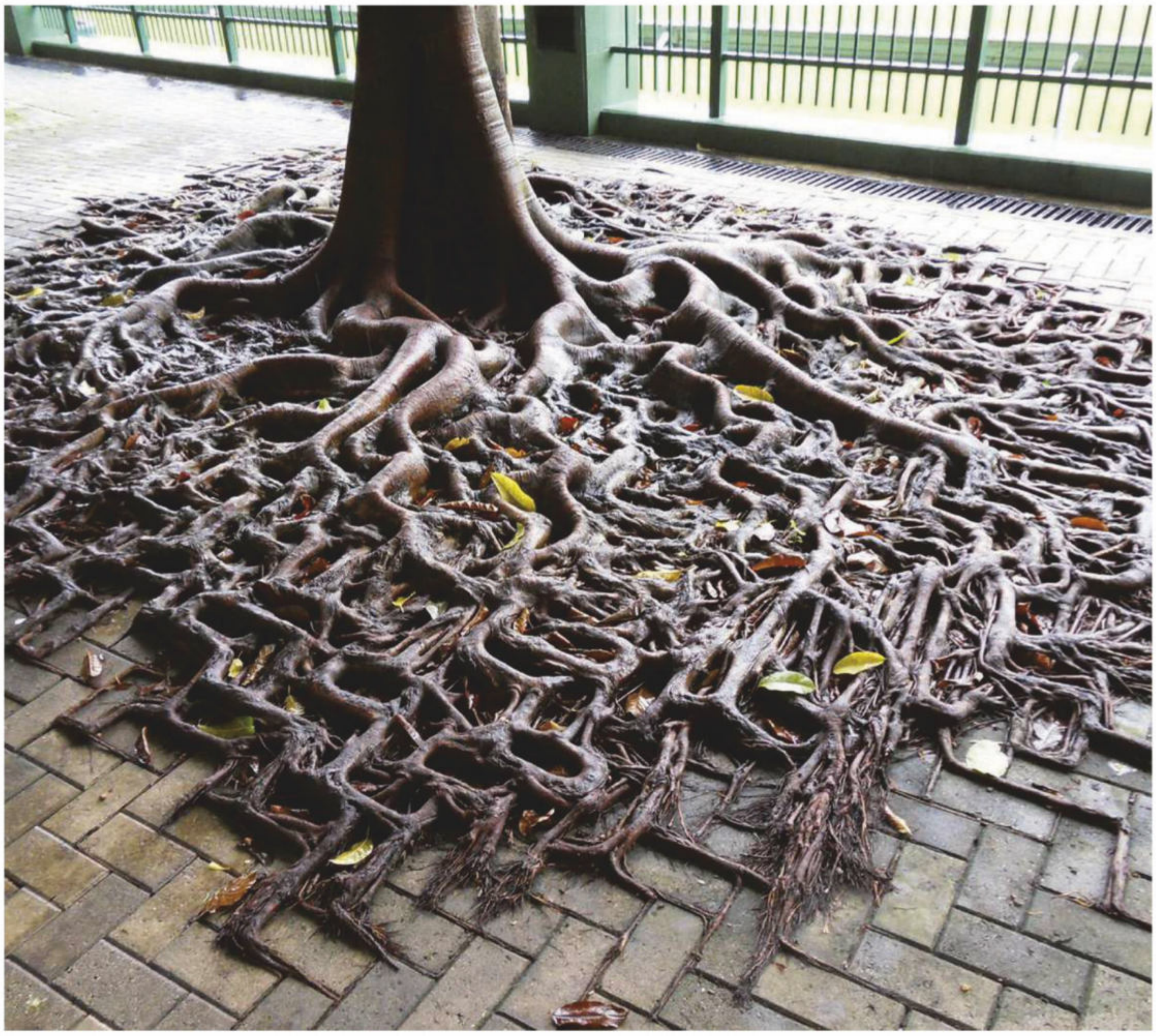
GREEN ABOUT THE HILLS

HOUTOUWAN, CHINA

In the 1990s, residents started leaving Houtouwan village on China's Shengshan Island. This hilly isle is part of the Shengsi archipelago, lying less than 100km from the bustling streets of Shanghai on the mainland.

In less than 30 years, Houtouwan has been entirely engulfed by vegetation. Only a decade before it was abandoned, it was a fishing village with 3,000 inhabitants. When the residents' demand for seafood began to outstrip what the island could supply, fishers took their families to the mainland, with a few later returning to show tourists around. Visitors like to peek inside the abandoned buildings, many of which have a museum-like quality, with remaining furniture and household items painting a picture of the recent past. However, locals have had to put up warning signs – some of the buildings are thought to be unsafe to enter due to creepers speeding up deterioration of the architecture.





CLEMENT BUCCO-LECHAT/WIKI COMMONS, GETTY IMAGES

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PUTTING DOWN ROOTS

HONG KONG, CHINA

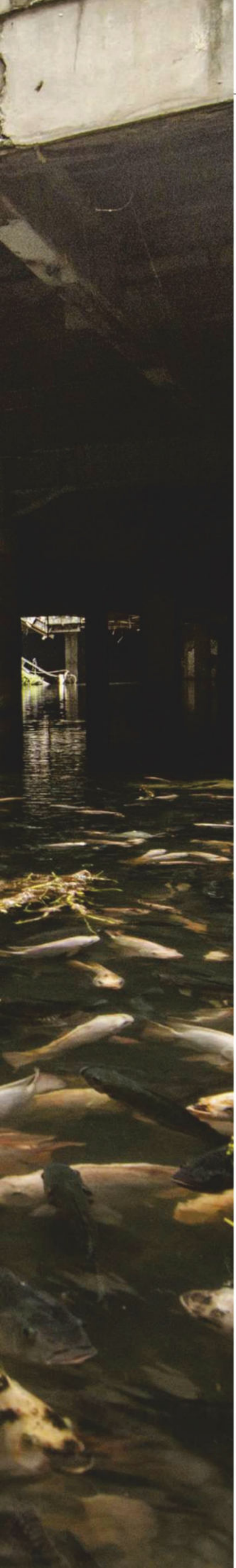
In China, the aerial roots of banyan trees cling to walls and protrude through pavements. Prof Chi Yung Jim, from the Education University of Hong Kong, is an expert on urban forestry and has counted over 1,100 banyans attached to the city's stone walls. "These wonderful doyens are the quintessential examples of nature existing harmoniously with culture in an exceptionally high density city," he says. Aerial roots are roots that grow above ground and are found in a wide variety of plant species. The neat, angular patterns formed by the roots in this picture demonstrate their slow search for water and nutrients along the narrow gaps between paving stones. These patterns are something to be relished while a banyan tree is still young, Jim explains, as they will eventually be diluted as the roots expand to fill the gaps between themselves.

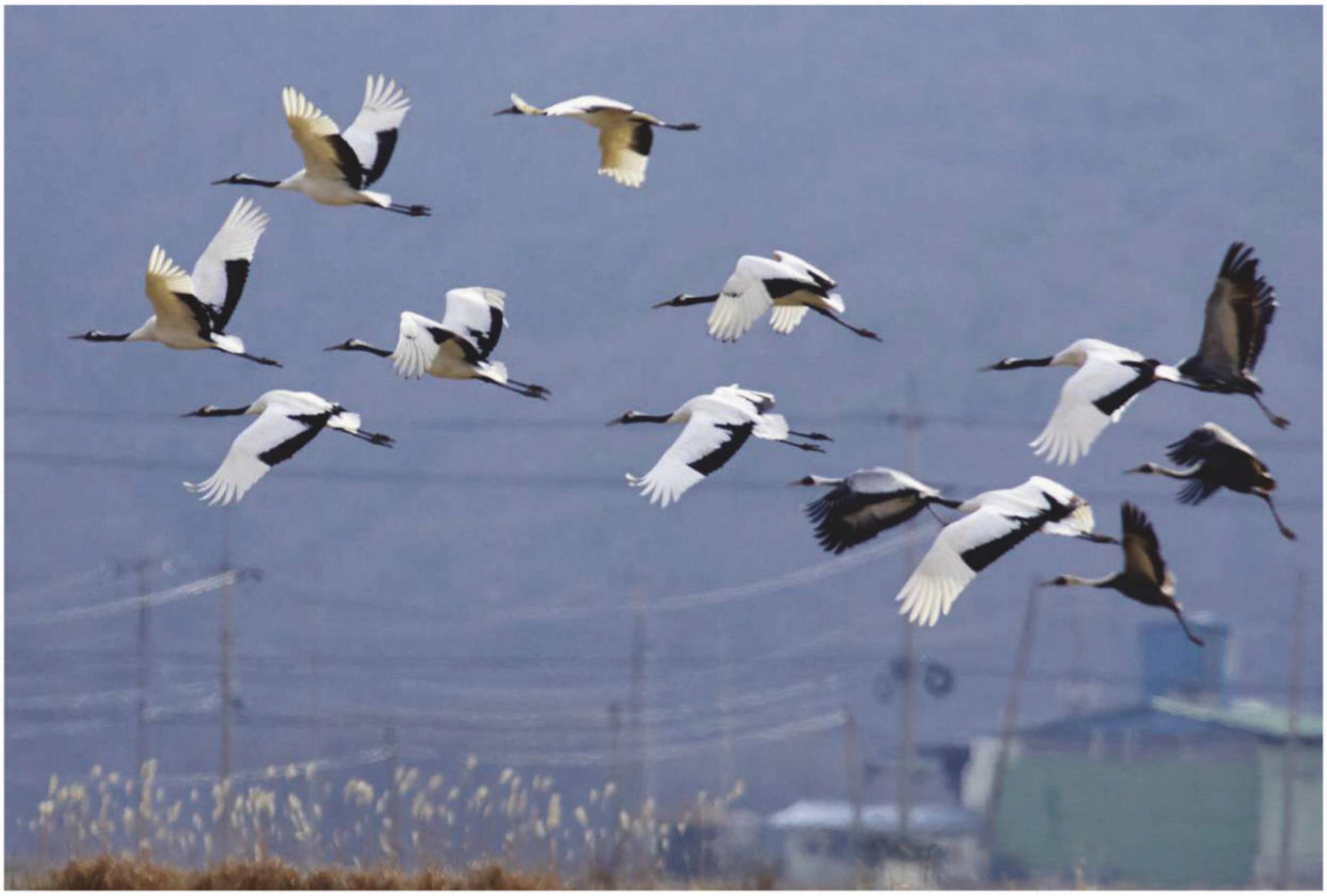
→

BUNNY BONANZA

ŌKUNOSHIMA, JAPAN

The island of Ōkunoshima is barely more than a kilometre wide but that's plenty big enough to accommodate a thousand rabbits. Better known as Rabbit Island today, this speck of land was once dubbed 'Poison Gas Island', because in the 1920s it was used for chemical weapons testing by the government. The bunnies' ancestry is up for debate. While some believe they are descended from lab rabbits brought here during the tests, others claim those rabbits were killed when the research ended and the current population stems from another source – such as releases by holidaymakers or local schools. Today, tourists can catch a ferry from the mainland, resulting in hundreds of TripAdvisor reviews. Though one visitor remarked on the surreal experience of a beautiful island being "overrun with tame bunnies and yet filled with threatening remnants of past atrocities."





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BIG FISH IN A MALL POND

BANGKOK, THAILAND

This Thai shopping mall near a tourist hotspot in Bangkok was half-demolished in 1997, due to a conflict over building codes. It then burned down two years later. But none of that stopped aquatic life from flourishing in the rainwater that slowly filled the building. It is thought that a few tilapia, catfish and koi carp were first introduced by an unknown person in the early 2000s in order to control the mosquitoes that were breeding in the water. Now, the fish number in the thousands.

Photographer Jesse Rockwell, who discovered the fish after venturing down a stairwell at the New World Mall, wrote on his blog: "[The fish] began to thrive and the result is now a self-sustained, and amazingly populated, urban aquarium."

↑

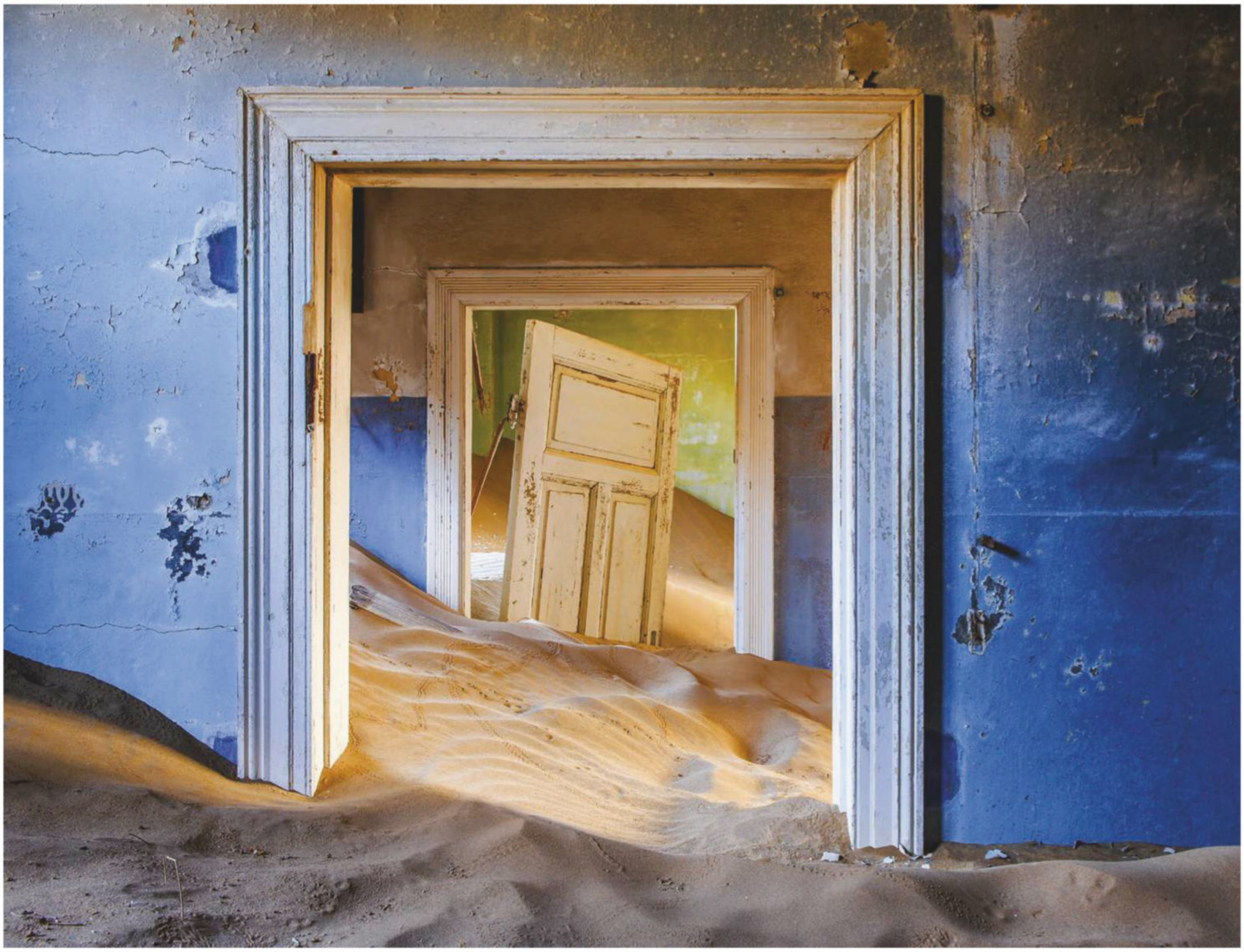
TWO BIRDS, ONE ZONE

DMZ, NORTH AND SOUTH KOREA

There's no love lost between North and South Korea, but there is a wilderness. This 250km-wide strip of land was farmland until 1953, when it was designated a demilitarized zone (DMZ) at the end of the Korean War. It might be guarded on all sides by soldiers, but inside it has become a sanctuary for wildlife – and notably, the cranes in this picture. The DMZ is the only place in the world where red-crowned and white-naped cranes still co-exist. The International Crane Foundation is collaborating with North and South Korean scientists to secure this important wintering ground for the birds.

Although the blur of their wings makes them hard to separate, this flock of mostly red-crowned birds is accompanied by a few white-naped individuals towards the back. The red-crowned crane is one of more than 100 endangered or protected species living in the DMZ. Siberian tigers reportedly prowl here too.

ALAMY, GETTY IMAGES



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DESERTED DIAMONDS

KOLMANSKOP, NAMIBIA

Early in the 20th Century, German mining companies descended on a patch of the Kalahari Desert served only by a small railway station, 10 kilometres from the Namibian coastline. By 1912, Kolmanskop, the town that emerged from the sand, was producing 12 per cent of the world's diamonds. Namibia was under German rule at the time and Kolmanskop quickly grew from a ramshackle collection of wooden buildings to an impressive display of European architecture, boasting a pub with a skittles alley and a music hall. However, when richer sources of diamonds were discovered further south, the fortune-seekers moved out and the sands swept in. The dry, windy climate of this coastal region moves the sand around a lot and by 1956 there was nobody left in Kolmanskop to sweep it up any more. As a result, it started piling up in the handsomely decorated buildings, now just remnants of a different time.

→

CAN'T SEE THE SHIP FOR THE TREES

PARRAMATTA RIVER, AUSTRALIA

Built to supply troops during WWII, the British freight ship *SS Ayrfield* now finds itself marooned in Homebush Bay on the Parramatta River, which runs to Sydney Harbour, Australia. The 70m-long freighter was still operating in the 1970s, but after its documents were cancelled, it found its final resting place in the bay. Although the hull was dismantled, the rest was left to rot. Over the years the ship has sprouted an unexpected cargo in the form of a mangrove forest.

As part of a regeneration project, there are plans to clean up the river, but the shipwreck should remain. "The mangroves that occur within the shipwreck are 'marine vegetation' that are important fish habitat and are protected," says Troy Holbrook, the senior open space and natural area planner for Parramatta. **SF**

GETTY IMAGES X2

by **HAYLEY BENNETT**

Hayley is a science writer based in Bristol, UK.

THE RACE TO CREATE A VACCINE

HOW SCIENTISTS WILL BRING AN END TO THE CORONAVIRUS PANDEMIC

by ANDY RIDGWAY

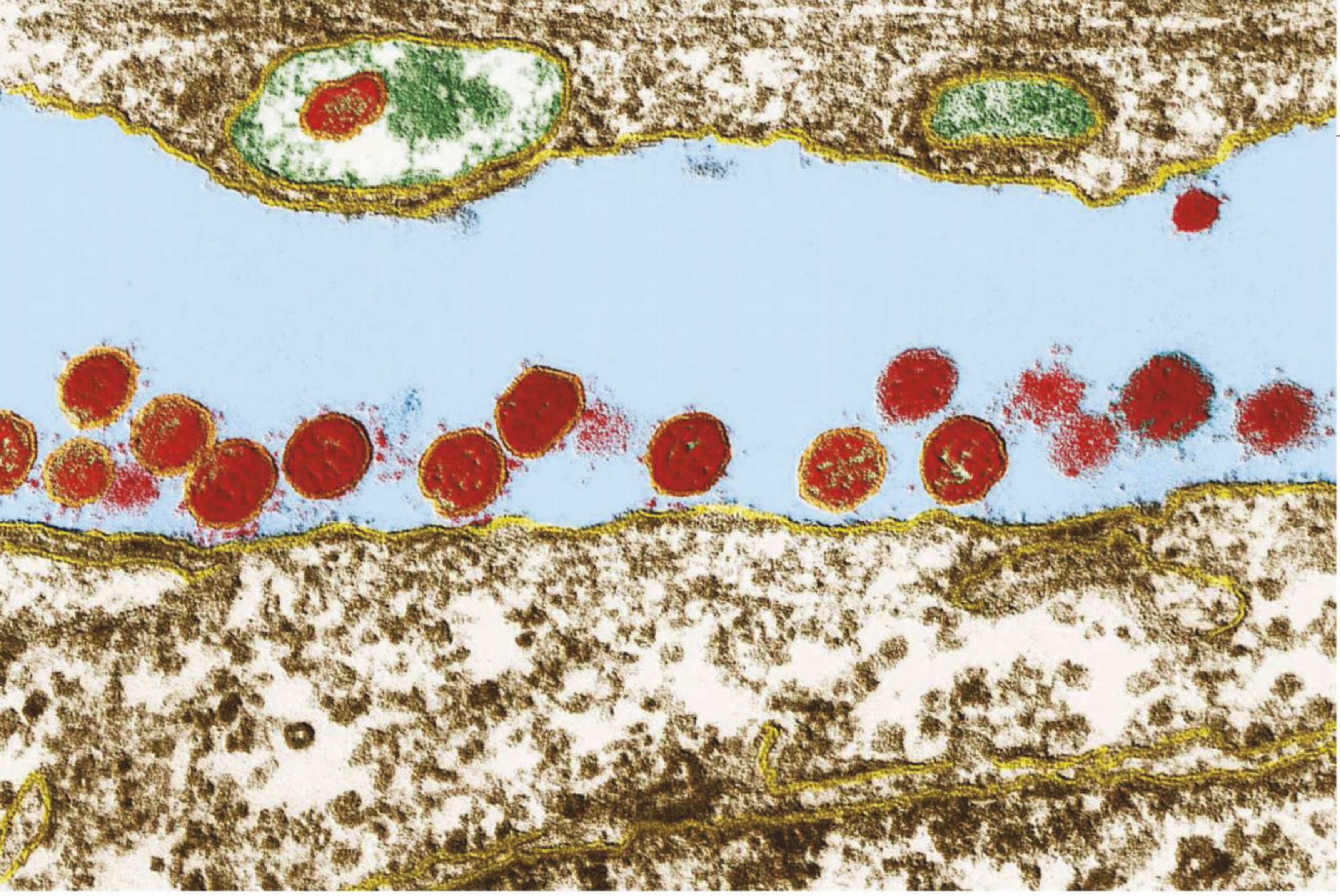
What were you doing on 10 January 2020? It was a Friday, so chances are you were arranging to meet up with friends. The days of completely unrestricted normality seem a distant memory. But it's the date that the race to create a coronavirus vaccine began.

That day, the Chinese government released the genetic sequence of the virus – SARS-CoV-2 – responsible for the pandemic. It enabled researchers around the world to start building bits of the virus in their labs, with the aim of developing a vaccine that will make us immune.

There are around 35 research teams around the world now working on a vaccine. Millions of pounds are being pumped into vaccine development by organisations and wealthy individuals, including Microsoft billionaire Bill Gates, who has pledged to build factories for the

ILLUSTRATION: MAGIC TORCH

MADE IN SWITZERLAND



LEFT SARS-CoV-2 viruses (red) are surrounded by a fatty outer layer covered with club-shaped protein spikes. The spikes allow the virus to gain access to our cells

> “GIVEN HOW WIDESPREAD THE VIRUS IS, IT SEEMS UNLIKELY THAT IT WILL JUST DISAPPEAR. THE SOONER WE HAVE A VACCINE, THE QUICKER CERTAINTY CAN RETURN TO OUR LIVES”

seven (as yet unannounced) leading candidates. Meanwhile, a handful of teams, including US biotech businesses Novavax and Moderna, and a team at the University of Oxford, are supported by a foundation called the Coalition for Epidemic Preparedness Innovation (CEPI).

The University of Oxford’s team is one of the furthest along the path to a vaccine. “I got the sequence on 10 January and then we spent the weekend deciding what to put in our vaccine,” says immunologist Dr Teresa Lambe, who is one of the vaccine team leaders at the university’s Jenner Institute. Since then, the work has been intense. “I haven’t had a weekend off. I’ve worked through gastro [a stomach bug]. I’ve worked through birthdays. I haven’t seen my children. It’s been exhausting.”

Since the pandemic took hold, there’s been a question that not even the experts can answer – when will it end? Given how widespread the virus is, it seems unlikely that it will just disappear. Even if one country eliminates it entirely, it could just take one infected person travelling from another country to reignite the virus’s spread. To stop it for good, we need immunity. So the sooner we have a vaccine, the quicker certainty can return to our lives.

THE PATH TO IMMUNITY

SARS-CoV-2 belongs to a broader group of viruses called the coronaviruses. Many just cause mild symptoms – nothing more than a cold. But a handful have caused serious disease outbreaks: SARS in 2002-2003, MERS from 2012 onwards, and now COVID-19 – the disease caused by SARS-CoV-2. We don’t yet have an approved vaccine for any coronavirus. But the urgency of this pandemic means that SARS-CoV-2 is now the top priority.

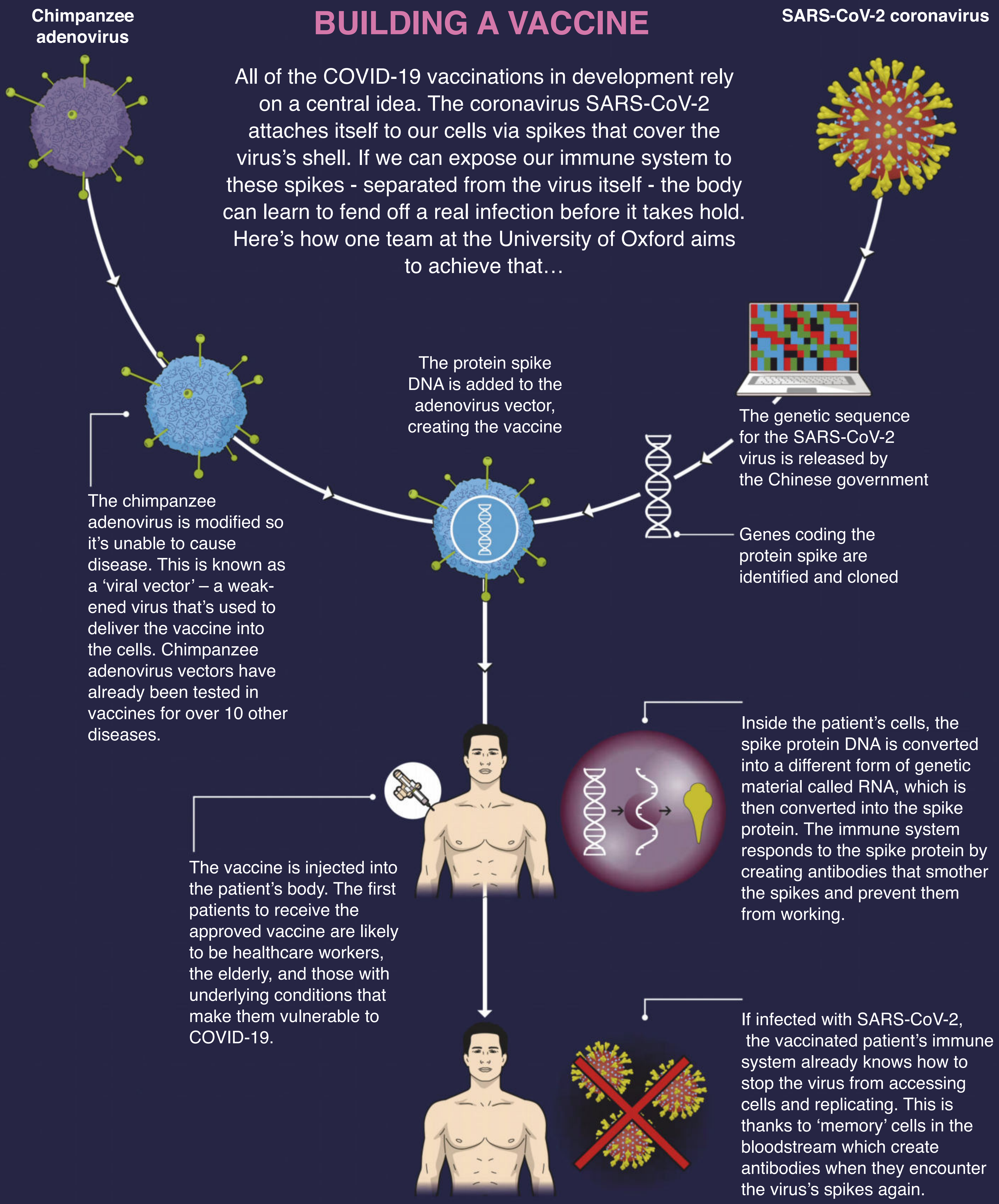
The basic principle of any vaccine is to fool the body into thinking that it’s been infected by the virus (or bacterium) that causes the disease. In response, the immune system creates proteins called antibodies. If you get infected by the real virus, memory cells in the immune system called ‘B lymphocytes’ produce the antibodies again, helping you to fight the infection.

All of the potential COVID-19 vaccines fundamentally achieve this in the same way, by exposing the immune system to the club-shaped protein spikes that cover the virus’s spherical shell. (This shell, made of fatty lipid molecules, encloses the virus’s genetic material.) When the virus invades our body, the spikes connect with a receptor on the surface of cells lining the throat and lungs to gain access to these

SCIENCE PHOTO LIBRARY ILLUSTRATION: ACUTE GRAPHICS

BUILDING A VACCINE

All of the COVID-19 vaccinations in development rely on a central idea. The coronavirus SARS-CoV-2 attaches itself to our cells via spikes that cover the virus's shell. If we can expose our immune system to these spikes - separated from the virus itself - the body can learn to fend off a real infection before it takes hold. Here's how one team at the University of Oxford aims to achieve that…



Chimpanzee adenovirus

SARS-CoV-2 coronavirus

The chimpanzee adenovirus is modified so it's unable to cause disease. This is known as a 'viral vector' – a weakened virus that's used to deliver the vaccine into the cells. Chimpanzee adenovirus vectors have already been tested in vaccines for over 10 other diseases.

The genetic sequence for the SARS-CoV-2 virus is released by the Chinese government

Genes coding the protein spike are identified and cloned

The protein spike DNA is added to the adenovirus vector, creating the vaccine

The vaccine is injected into the patient's body. The first patients to receive the approved vaccine are likely to be healthcare workers, the elderly, and those with underlying conditions that make them vulnerable to COVID-19.

Inside the patient's cells, the spike protein DNA is converted into a different form of genetic material called RNA, which is then converted into the spike protein. The immune system responds to the spike protein by creating antibodies that smother the spikes and prevent them from working.

If infected with SARS-CoV-2, the vaccinated patient's immune system already knows how to stop the virus from accessing cells and replicating. This is thanks to 'memory' cells in the bloodstream which create antibodies when they encounter the virus's spikes again.

FIVE ALTERNATIVES TO VACCINES

While we wait for a vaccine, the World Health Organization (WHO) has launched a global trial of drugs that could be used to treat those who already have COVID-19...

The enzyme inhibitor

Remdesivir is the frontrunner in the trial. It was originally developed by US biotechnology company Gilead Sciences to treat Ebola. It inhibits an enzyme called 'RNA-dependent RNA polymerase' that viruses need to replicate. A study in 2017 showed that it can inhibit the SARS and MERS coronaviruses. The first COVID-19 patient in the US was given remdesivir when his condition deteriorated, and a case report in the *New England Journal Of Medicine* said that his condition improved the next day.

The malaria medicine

Chloroquine and hydroxychloroquine are two drugs usually used to treat malaria and, among other conditions, rheumatoid arthritis. There have been reports from China that chloroquine was an effective treatment for COVID-19, and a trial of hydroxychloroquine in France showed it reduced numbers of the virus in nasal swabs. But many virologists are being cautious, pointing out that hydroxychloroquine has been studied as an antiviral for years, but trials have not worked out.

"EXPOSING THE IMMUNE SYSTEM TO THE SPIKES ON THE VIRUS'S SHELL, WHICH ARE HARMLESS ON THEIR OWN, TRAINS OUR BODY TO QUICKLY CHURN OUT ANTIBODIES"

LEFT The director-general of the World Health Organization, Dr Tedros Adhanom Ghebreyesus, has been overseeing the management of the COVID-19 pandemic

cells, allowing the virus to enter and replicate. But exposing the immune system to these spikes, which are harmless on their own, trains our body to quickly churn out antibodies that smother the spikes and stop them from connecting.

Each team has its own twist on this approach. The vaccine being developed at Oxford University involves injecting the genetic sequence (the DNA) of the protein spike into the blood. Our cells will use this DNA to manufacture the spike, triggering the immune response. Moderna's approach, meanwhile, involves injecting the spike's genetic material in a different form (RNA instead of DNA). And a vaccine being developed at the University of Pittsburgh injects the spike protein itself on a patch of microneedles – the patch would be stuck on like a plaster, and the tiny needles would dissolve once they'd pierced the skin.

To deliver the spike's DNA to our cells, the Oxford researchers are packaging it inside a 'viral vector' – essentially a delivery virus. This is a modified chimpanzee virus belonging to a group of viruses called the 'adenoviruses'. "The vector has been crippled," says Lambe. "It doesn't replicate and it doesn't cause disease."

The HIV treatment

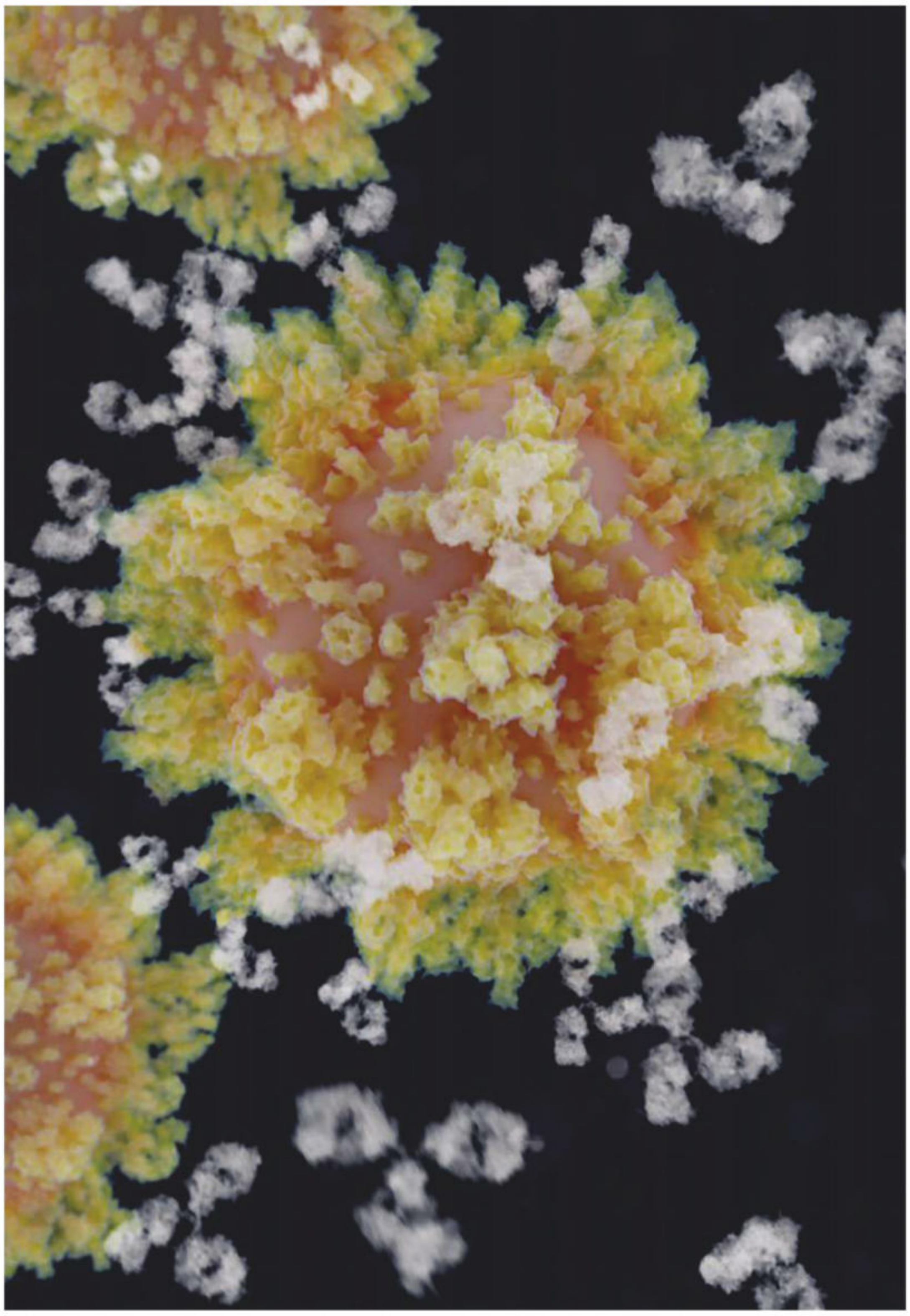
Ritonavir and lopinavir is a combination drug – both are given together – and it's already used to treat HIV infections. It works by blocking a type of enzyme called a protease, which is used when new viruses are being built. It's known to work with other viruses, too – including coronaviruses. A trial in Wuhan, China, didn't fare well, with the patients not doing any better than those not given the drugs. But the doctors involved said that the patients given the drug may have been too ill to benefit.

The drug cocktail

One blend of medicine combines the antiviral HIV drugs, ritonavir and lopinavir, with interferon beta, a protein which regulates inflammation in the body and is used to treat multiple sclerosis. This combination is already being tested in a trial in Saudi Arabia as a treatment for the coronavirus that causes MERS. A separate trial, involving University of Southampton researchers, is testing interferon beta on its own in COVID-19 hospital patients in the UK.

The plasma injection

While not part of the WHO trial, the idea behind convalescent serum is simple. People who have recovered from COVID-19 will have produced antibodies to fight off the virus. So why not take some of their blood, separate off the plasma that includes the antibodies, and inject it into COVID-19 patients? Convalescent serum has already been used to treat SARS and MERS. The US Food and Drug Administration (FDA) has approved a trial against COVID-19 at dozens of hospitals across the US.



GETTY IMAGES, SCIENCE PHOTO LIBRARY

LEFT Illustration of antibodies responding to a coronavirus infection

At the time of writing, two vaccine developers have launched human trials: Moderna and China's CanSino Biologics (CanSino also use an adenovirus-based viral vector). But Oxford isn't far behind, with trials scheduled to begin at the end of April or start of May.

TESTING TIME

After receiving the virus's genetic sequence in January, the Oxford team's first step was to identify the spike's DNA. This DNA was then cloned and used to create a vaccine for pre-clinical tests. "Before it goes to clinical trial, every vaccine or drug has to be assessed in animal models," says Lambe.

The pre-clinical tests have shown that the vaccine is effective at producing antibodies that stop the SARS-CoV-2 virus from binding with cells. The vaccine also boosts levels of a type of white blood cell called T cells – another weapon in the immune system which kill virus-infected cells, slowing the virus's replication.

Meanwhile, the University of Oxford's Clinical BioManufacturing Facility is making a larger volume of the vaccine that will be safe to go into humans, ready for the first clinical trials.

In phase I of the trials, the focus will be on the vaccine's safety. "You inject a volunteer with a dose you know is safe from other clinical trials [with similar vaccines]," says Lambe, "and you monitor them carefully for the next two to three days." As well as checking the vaccine is safe, by looking for side effects such as muscle aches and headaches, the ➲

ABOVE A cyclist rides along London's eerily empty Regent Street during the UK lockdown

researchers will measure the levels of T cells and antibodies in the volunteer's blood. By the end of phase I, the plan is to have injected 510 people aged 18-55.

If the vaccine looks to be safe and functional, then it's on to phases II and III. Phase II will extend phase I to those aged 56 and over, as well as a small number of children. Phase III will involve 5,000 volunteers aged 18 and over, with half of them receiving the COVID-19 vaccine. This phase will test whether the vaccine offers protection in the real world, by monitoring the vaccinated individuals and comparing their COVID-19 infection rate to that of those who don't receive the vaccine in the trial.

THE WAITING GAME

It's impossible to rush the watching, the measuring and the waiting that is the stuff of clinical trials. Regulatory bodies also need time to check the safety and effectiveness of new vaccines, and even once a vaccine is approved, there's the potential for a delay while vaccine manufacturers ramp up production. "You don't want to start manufacturing stuff until you know it is actually going to work," says Dr John Tregoning, an expert in respiratory infections and vaccine development at Imperial College London.

The Oxford team is trying to smooth the path to mass production. "In parallel to the trials, we are working really hard on scaling it up so that we are in a position, probably by the end of the year, to have a lot of doses available, probably in the millions," says Lambe. The vaccine would not initially be freely available, but would be given to those identified as a priority (see 'Who will get the vaccine first?', left).

The other frontrunners are working to similar timescales. Most

WHO WILL GET THE VACCINE FIRST?

When a vaccine for SARS-CoV-2 is developed, it will initially be in limited supply as production is ramped up. So priority is likely to be given to healthcare workers who are in contact with COVID-19 patients. Older people and those with underlying health conditions would also be a priority, as they are most likely to become seriously ill.

If you don't fit into one of these categories, you will have to wait a little longer. "I doubt that in a year we're going to see this given to you and me," says Dr Maria Bottazzi, part of a team developing a COVID-19 vaccine at Baylor University in Texas.

Taking a global view, there's also the question of how evenly the COVID-19 vaccine will be distributed between countries. During the 2009 H1N1 (swine flu) pandemic, rich countries placed advance orders with vaccine manufacturers, leaving poorer nations less well supplied. There are also concerns that vaccine makers in developing countries will struggle to make COVID-19 vaccines if the first ones to be approved use newer technologies. These are all questions that will have to be addressed as we get closer to an approved vaccine.

COVID-19
Antibodies

TESCO Bank
Cash Machine
Cash Machine
Straight to the poi

LEFT Measures to restrict the spread of COVID-19 have transformed our lives

> “YOU WANT DISPERSED, LOCAL MANUFACTURING, AND A PROCESS THAT’S QUICK AND EASY TO REPLICATE. SO THE MORE DIFFERENT VACCINES THERE ARE, THE QUICKER YOU CAN GET A VACCINE TO PEOPLE”

estimates put COVID-19 vaccines as being available in a year to 18 months – an incredible feat as it typically takes 10 or more years to develop a vaccine and get it approved. The race may ultimately end with several vaccines by several developers in production. “When you get to the point where the world needs to scale up vaccine production to billions of doses, it will be better not to be using just one technology in one factory,” says Tregoning. “You want dispersed, local manufacturing, and a process that’s quick and easy to replicate. So the more different vaccines there are, the quicker you can get a vaccine to people.”

But when this is all over, and we’ve got a vaccine, where does it leave us? Deadly coronaviruses have a nasty habit of appearing out of nowhere. Might we just be faced with another vaccine race when the next one emerges?

Dr Shibo Jiang at Fudan University in China says he has a solution. Working with colleagues in China and the New York Blood Center in the US, he has developed a type of molecule called a peptide that can latch on to a specific region of the SARS-CoV-2 protein spike, stopping the virus from getting into cells. The research is published in the journal *Cellular & Molecular Immunology*. Crucially, this region of the protein spike is similar in other coronaviruses, so it means that this molecule could potentially work as a vaccine or treatment for future coronaviruses, too.

“This treatment is not injected; it would be inhaled,” Jiang tells *BBC Science Focus*. “You could use this in your home – you wouldn’t need to go into hospital.” He says the one thing holding up the research at the moment is the money needed to do the pre-clinical research.

But if the money becomes available and the research pays off, it might mean that scientists won’t be confronted with another frantic battle against a coronavirus again. And neither will we. **SF**

by **ANDY RIDGWAY**
(@AndyRidgway1). Andy is a freelance science writer based in Bristol.

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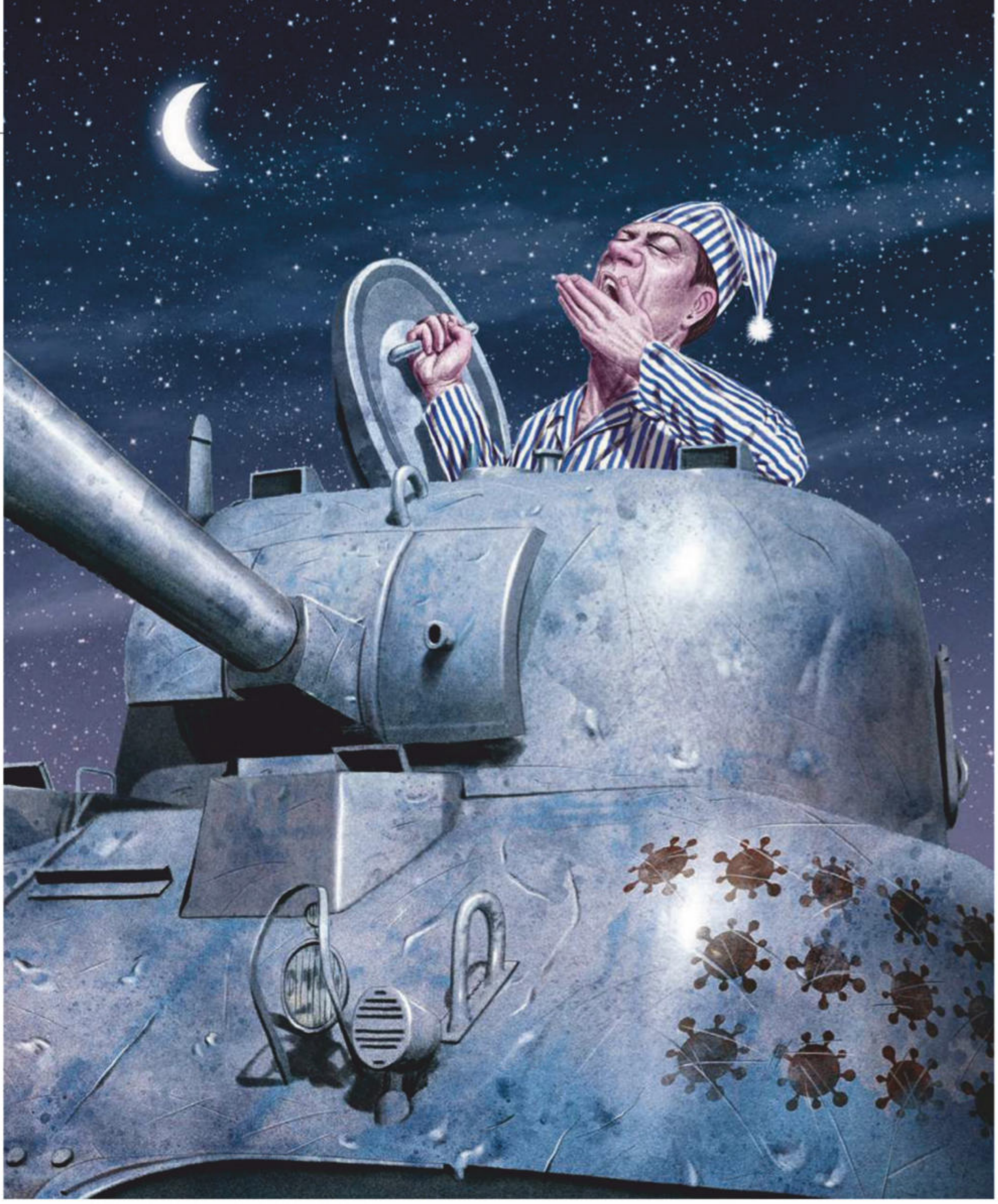
COMMENT

SLEEP TIGHT

How a good night's sleep can protect you against COVID-19



Like everyone else, I have been overwhelmed by the speed at which COVID-19 has emerged from nowhere and threatened our way of life. At the end of December, it was just a few 'flu-like cases' in Wuhan. Now it is a pandemic, which, for many people, has only just begun.

I've seen it up close, as two of my sons have had it. One of them, Daniel, returned in mid-March from Australia where he had been sharing a flat with two doctors. A few days later he got a call from one of his former flatmates saying he had tested positive for COVID-19, as had four other of their mutual medical friends.

The following day Dan got all the classic symptoms, including cough, fever, headache and loss of taste or smell. I'm glad to say that within a couple of days he was fine. His older brother, Jack, who is a doctor working in a respiratory ward near Manchester, which was full of patients with COVID-19, also went down with the same symptoms. Like Dan, he was soon well again, though he has yet to recover his sense of smell.

I am 63 years old and male, which puts me into a much higher risk category. As well as washing my hands and isolating, one of my top priorities is getting a good night's sleep. That's because a good night's sleep is vitally important for keeping your immune system in great shape. Numerous studies have shown a clear link between stress, poor sleep and vulnerability to viral infections.

We know that while you are in deep sleep your body makes and release cytokines, which are proteins that function as chemical messengers for regulating your innate and adaptive immune response. Quality sleep is also important for the production of infection-fighting antibodies and cytotoxic T cells (also known as killer T cells). A recent study showed that the ability of killer T cells to bind to and destroy infected cells was reduced after a single night of poor sleep.

> "Those who slept less than six hours were four times more likely to get a cold"

The importance of getting a good night's sleep in fighting off viral infections was highlighted by a fascinating study, carried out in 2015 by researchers from the Universities of California and Pittsburgh in the US.

For this study, 164 healthy men and women, aged 18 to 54, were recruited to wear sleep trackers for a couple of weeks, and researchers also kept a record of how well they slept. The volunteers were then brought into a lab and asked to inhale nasal droplets containing cold-inducing viruses.

The volunteers were kept isolated, in a nearby hotel for another five days to see if they got infected, as measured by the presence of the virus or a four-fold increase in an antibody response. And, if they were infected, did they develop symptoms?

Of the 164 participants, 124 (75.6 per cent) became infected, and 48 (29.3 per cent) developed a biologically verified cold. One of the striking findings was that those who slept less than six hours a night were four times more likely to actually get a cold than those who got seven hours or more. That's a great reason to prioritise a good night's kip. **SF**

MICHAEL MOSLEY
Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *Fast Asleep* (£9.99, Short Books).

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: JASON RAISH

COMMENT

A LEARNING CURVE

There's nothing like a nationwide school closure to help you recognise the valuable work that teachers do, every single day

Before COVID-19, my daughter and I had a joke. If we got on each others' nerves, we'd say, "there's always homeschooling… !" And then we would burst out laughing because, no, not in our house there wasn't. I am not made of that stuff. I have friends who are teachers, I have family who are teachers. They are gods and goddesses. Nothing phases them. I am not that.

And so, when the inevitable school closures were finally announced a few weeks ago, the prospect of being responsible for our five-year-old's education filled me with terror. I'm prone to overthinking and chronic FOMO (Fear Of Missing Out), so I spent a considerable number of sleepless nights fretting over everything to do with education. How would she learn? How would I work? How would I teach her the right thing? Would I mess her up? Would she fall behind? What do I do with all these helpful offers from organisations I'd forgotten I'd signed up for that are clogging my inbox? It's not a pretty place in my head. It's a wonder I get anything done.

And then I tipped over the precipice of panic and found a zen den of calm like nothing I'd experienced since the hormonal rush of the last few weeks of pregnancy. It came from a moment of realisation that we are in a time of unprecedented access. We have digital discovery walks at our fingertips, libraries of experiments to explore, and decades of robust pedagogical research behind quality television and interactive programming. These resources are supporting generations of future adults in accepting what will be will be. That's a lesson for us all.

> **"I hope that there will be proper recognition of the epic work teachers do. Teachers put knowledge into our little ones, and they help raise them to be good people"**

Parents, carers and guardians are not teachers, and we are not expected to be. We don't need to meet key requirements or core objectives. We need to back off from trying to manage the work that other people are trained to do, because they are the experts. And a suite of learning apps does not replace the teacher or the classroom.

There are over a billion children worldwide who are out of school, and that's a billion children who will be back up to speed after they have some time with their teachers again. That will be a culture shift for the schools, but one that they are trained for. There are many things that will come out of this disruptive moment. I hope that one will be proper recognition of the epic work that teachers do for our kids. They put knowledge into our little ones, and they help raise them to be good human beings.

So despite the school closures, homeschooling isn't happening in our house, still. We are learning what we need to, and learning how to learn (and occupy ourselves). Screens are on sometimes, and play is happening. And this episode will transform the learning experience for a lifetime. SF

ALEKS KROTOSKI
Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human.*

PORTRAIT: KATE COPELAND ILLUSTRATION: SCOTT BALMER

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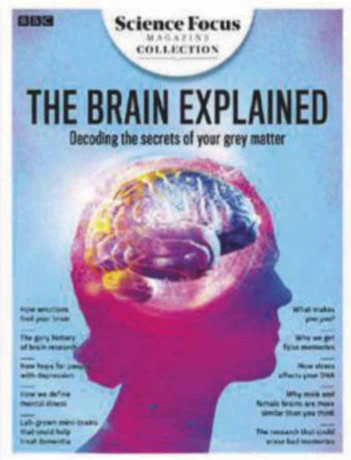
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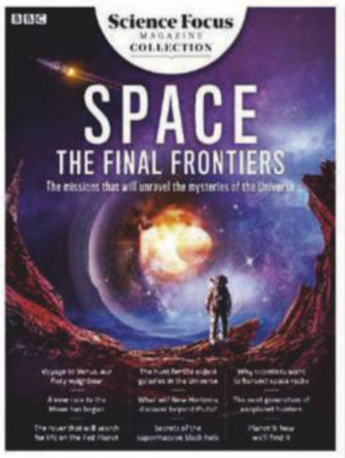
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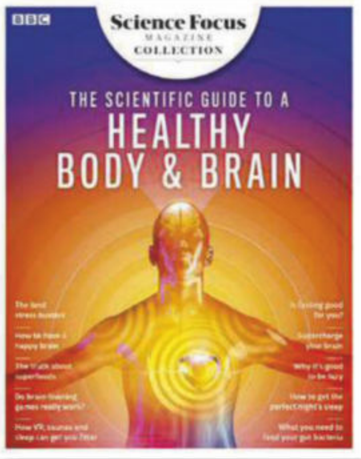
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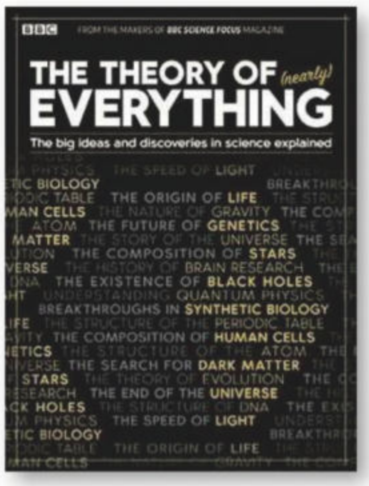
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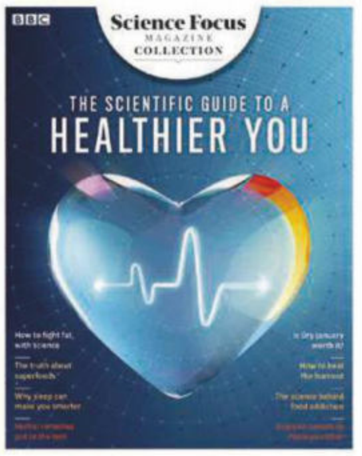
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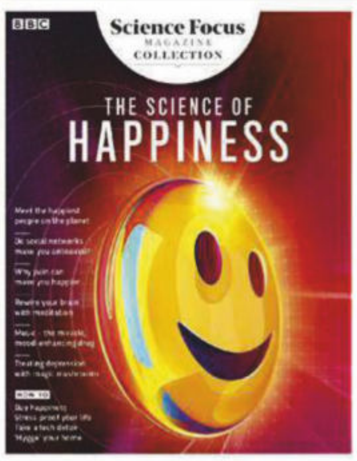
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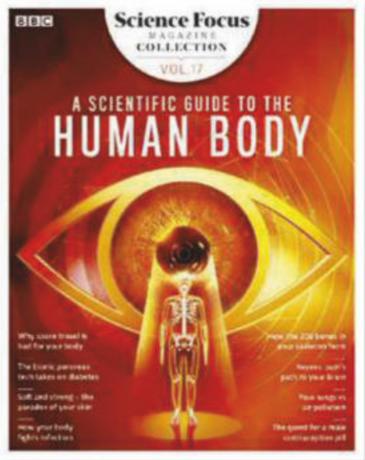
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INTERVIEW

KNOW YOUR MIND

Our brain uses shortcuts to think quickly, but sometimes these mental timesavers let us down. **Dr Pragya Agarwal** talks to **Amy Barrett** about the science of cognitive biases, and why it's more important than ever to understand how they hold sway over our views

WHY DO WE HAVE BIASES?

In evolutionary terms, we are designed to differentiate between people, and make those quick decisions between people who belong to our group, or our tribe, and those who don't. That was kind of a survival strategy because resources were limited and people had to say, "this is a threat to me or to the limited resources, and so this person is an out-group."

We make these quick decisions about whether this person or an object is a threat, or should we fear this person. These kind of in-group, out-group demarcations are made quickly, because we have to process so much information. There's no time to take every bit of information on a rational, logical level. So, a lot of this is processed on the basis of our previous experiences. We make these quick matches between our previous experiences, say, in the past, this kind of person or situation was a threat to us, so that is what this will be.

That's how these immediate stereotypes are formed. We rapidly make demarcations and distinctions and labels, as a way of processing information really quickly before we can take it to a rational level in our brain.

ARE THERE BENEFITS TO THIS?

Absolutely. Say I go shopping and want to choose a brand of cereal in the supermarket. If I took every bit of information around me and weighed it up and tried to make an independent decision based on clear analysis, then there's not enough time. I would be stuck with every decision in the world.

But there are obviously negative sides to it in certain situations and where these decisions actually make an impact. They have life and death impact. They're more important than just choosing a brand of cereal.

HOW DOES SOCIAL MEDIA FIT INTO THIS?

Some of the discourse around biases and prejudices can become quite heated, because they can feel like a judgment on our whole identity. We say that you are biased, so you are a bad person.

What I'm trying to do in my book is, by giving scientific evidence and bringing in different case studies and theories, to help us understand that we can all unlearn some of our toxic behaviours. Yes, social media is creating echo chambers ►

> “We cannot just do away with all our cognitive biases, all our implicit biases. But we can do away with the stereotypes, prejudices and discrimination that is linked to some of the biases we carry”

and filter bubbles. Social media is strengthening the sense of belonging in a particular community, that “I belong in a particular tribe, so I cannot engage with anybody who does not belong in that.” Again, we’re falling back on primal in-group, out-group tendencies through these mediums. But I also think that these divides are being reinforced by the climate in which we live.

If a marginalised community starts talking about and pushing back against prejudices, then there will be further divides initially. But having more evidence, and open-minded, non-judgmental platforms for these discussions is important.

TELL US ABOUT THE TYPES OF BIASES.

An explicit bias is something that is very clear. If somebody purposefully discriminates between two people based on their race or skin colour, or how much they earn, and it’s clear that this discrimination is happening or these prejudices exist, then that is an explicit bias.

But there are also implicit ones, which are more difficult to identify as biases. These affect our decisions and our actions, but they are not very clear. For instance, making fun of somebody, or preferring one person over another: if someone looks at a CV and says, “Oh, I think this person is more qualified than the other,” just because they went to a certain university.

All of us also carry a conformity bias; we are more attracted to people who are more like us. Those kind of biases are not easy to mark out.

ONCE YOU’RE AWARE OF UNCONSCIOUS BIASES, CAN YOU TRAIN YOURSELF OUT OF THEM?

There’s a whole debate about whether unconscious bias is something we’re born with or whether we can unlearn them. Personally, I believe that a lot of these biases are learned and shaped through our experiences. The way that we have been brought up, the cultural and social context, the media we’ve been exposed to, the things that our tribe and our community tell us, the things we talk about or we read in newspapers. We learn them through our lifetime. And because we learn them, we can unlearn them as well. I believe that once we become aware of them and we reflect on them, we can change our attitudes accordingly.

SO, THINGS IN YOUR CHILDHOOD APPEAR LATER IN LIFE AS UNCONSCIOUS BIASES?

Yes. In my book, I talk about developmental psychology, and how children, as they’re growing up, start forming the sense of in-group and out-group associations. That’s a natural response for children, because they’re making sense of their own identity, their own place in the world. It’s largely shaped by who they see around them, who they see as foes, who they see as friends, who they find comfort with. There’s no real prejudice involved in that stage, but prejudices are bolstered and reinforced by messages they might get from their parents, or from their education, or the books they read and the TV that they watch.

DO YOU SEE A FUTURE WITHOUT THESE BIASES?

No. I don’t think so. I think change will happen, and is happening slowly – very slowly, because there is always resistance to any kind of change in status quo. People who have privilege will always resist, because that threatens their status, and that means they worry about what their position and place in society will be once their status changes. It’s important that we talk about it, that we become aware of things [that arise from biases] like micro-aggressions. Things that were acknowledged and ingrained as part of our culture, and accepted as okay, even though it hurt the person who was being marginalised or victimised.

We cannot just do away with all our cognitive biases, all our implicit biases. Bias is not always negative. But we can do away with the stereotypes, prejudices and discrimination that is linked to some of the biases that we carry.

HOW DO YOU STUDY PEOPLE’S BIASES?

It’s difficult to measure and quantify these things. In my book I critique some of the tools and methods which have been considered as the absolute one way that we can measure bias. Like the Implicit Association Test (IAT), for instance. The IAT was proposed by Harvard psychologists

DR PRAGYA AGARWAL

Pragya is a behavioural and data scientist, ex-academic, and a freelance writer and journalist. She runs a research think tank called The 50% Foundation, which is for gender equality.

Her book, *Sway*, emerged out of her own academic research, and her interest in how bias and uncertainty gets built into data technology. It was also based on her personal experience as a woman growing up in India and in the UK, in a predominantly white male environment of technology and STEM. It was inspired by her role as an academic, being the first woman lecturer in a leading engineering department in one of the top five UK universities, being a single parent, and being a woman of colour. These all shaped her sense of belonging and the kind of biases faced through her life.

ASADOUR GUZELIAN

and it has been used for a long time, because we don't have any other test. It's a useful tool, but some people think it gives a measurable value for what implicit bias is. It works on the basis of association and in that way, it tells us what our implicit biases are. If I associate a certain thing with a certain thing. For example, if I say apple = green all the time, then obviously I believe, firmly, that apples are always green and they can never be red. That's very simplistically speaking. And the IAT will give these associations a value, but that number doesn't really give you the absolute marker for what kind of biases we carry.

I see the IAT being used a lot by organisations. They call it 'diversity training', or 'implicit bias training', but it's not training you to understand about what implicit bias is, and how to tackle it.

CAN A COMPUTER BE BIASED?

We might think that AI is neutral – that is certainly how people promote AI-based hiring and recruitment platforms. People say that, because it's technology, it will do away with human biases. But that's completely incorrect because machines are not black boxes; they are being designed by humans and building on the data that exists.

So, all the biases from the team, developers, from the data, are really enforced and built into the system itself. But when these systems and technology again create these biases, it can perpetuate the biases that already exist in society as well, so it becomes kind of a vicious cycle. We need to be so careful when we use technology and machine learning.

BUT THIS ISN'T JUST HIGH-TECH STUFF, IS IT? IT'S IN OUR HOMES AND IN OUR PHONES.

Yes, absolutely. The problem with tech, and in STEM, is that most of the developer teams [that design the tech] are largely male-dominated. There are studies that talk about instances of sexism and misogyny in Silicon Valley. Those kind of biases within teams can get built into the technology or systems they're creating. So, giving voice assistants feminine voices, or female names, creates and reinforces the notion that women are in a subservient or an assistant role. That they can be talked to in a dominating way, and they will not retort or stand up for themselves. There was a report by the UN a couple of years ago which revealed that, in reply to hearing something sexually demeaning, a voice assistant would only say, "I'd blush if I could".

I think a lot of organisations are beginning to take these concerns on board. I know that there have been changes in the way voice systems have been designed, and the things they can say in response to sexual harassment statements.

BUT WE NEED TO ADDRESS THESE THINGS AT THE BEGINNING, BEFORE THE TECH RUNS AWAY FROM US.

Absolutely. **SF**

ABOVE Behavioural scientist Pragya Agarwal

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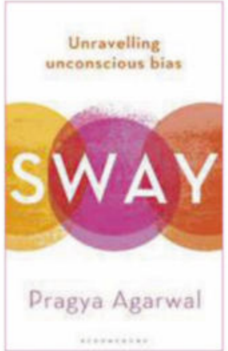
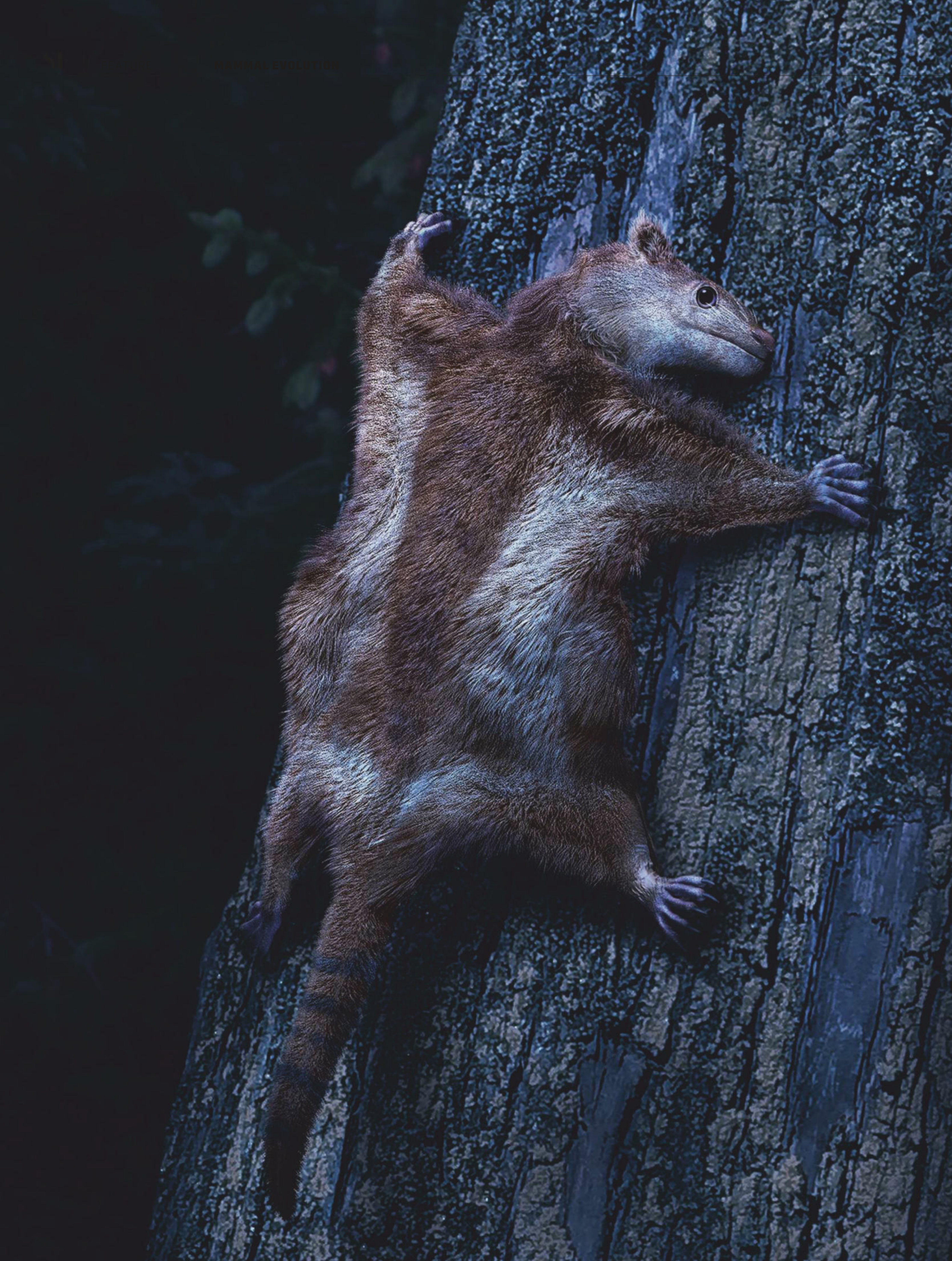
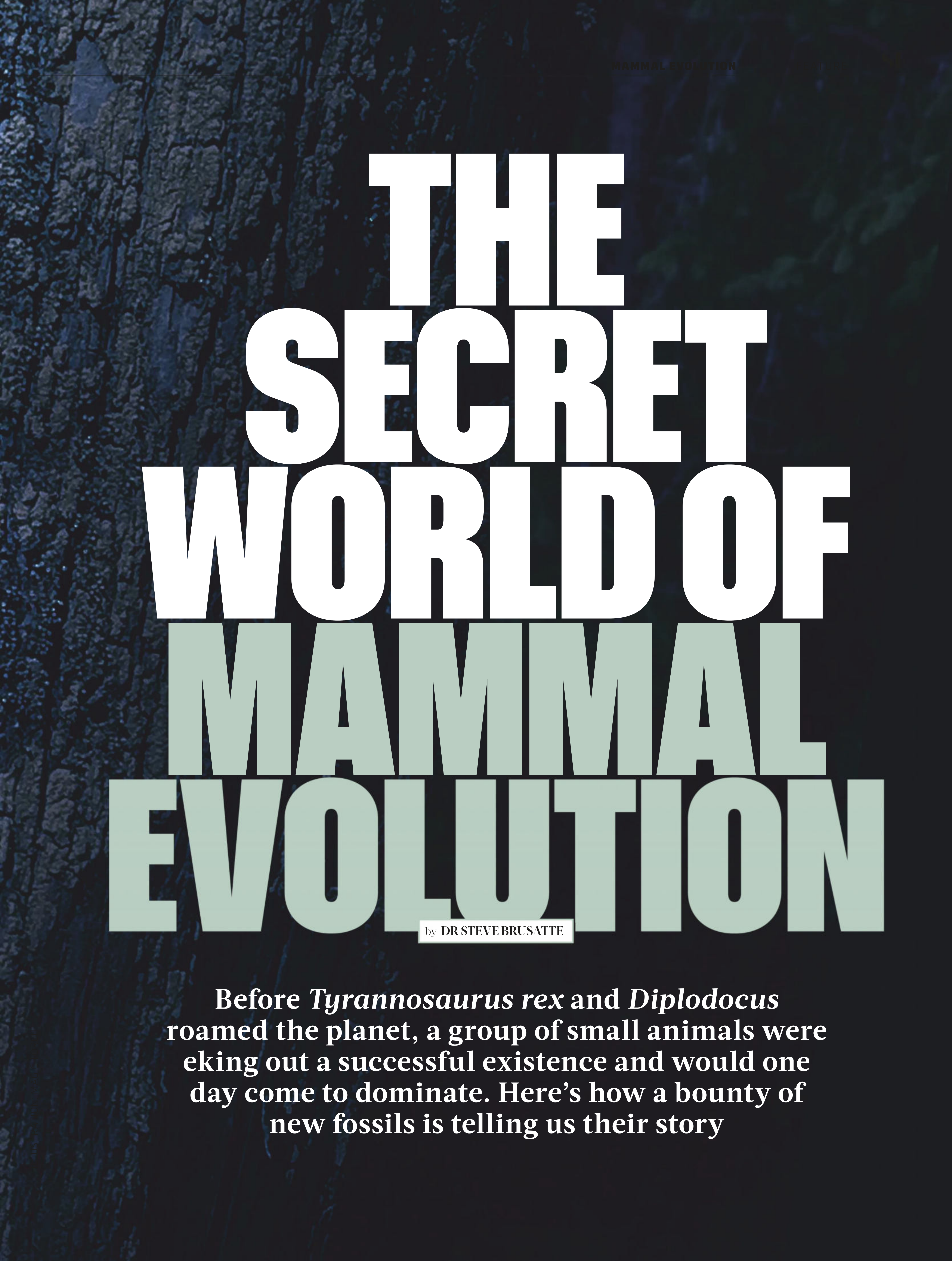






THE SECRET WORLD OF MAMMAL EVOLUTION

by **DR STEVE BRUSATTE**

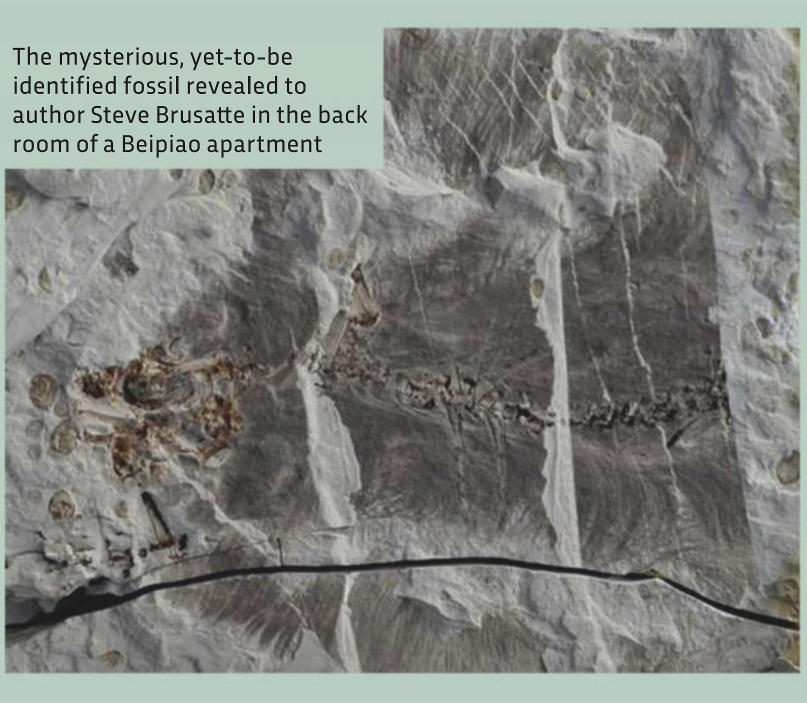
Before *Tyrannosaurus rex* and *Diplodocus* roamed the planet, a group of small animals were eking out a successful existence and would one day come to dominate. Here’s how a bounty of new fossils is telling us their story

A few years ago, I visited Liaoning Province in China, to study the region's famous feather-covered dinosaur fossils. One day, after many hours of measuring bones and photographing feathers in a museum, I needed a break. My Chinese colleagues exchanged a few hushed words of Mandarin and motioned for me to follow. "We have something secret to show you," one of them said. "And it's not a dinosaur."

We left the museum, hopped into a car, and snaked through the narrow streets of Beipiao city, clogged with bicycles and noodle vendors. We pulled into an alleyway that opened into a small courtyard. Into a dark apartment we ventured, sidestepping a clutter of boxes and wooden crates. One of my colleagues ducked into a side room and came out holding two rock slabs that fitted together like a jigsaw puzzle. On the surface was a brown smear, about the size of an apple.

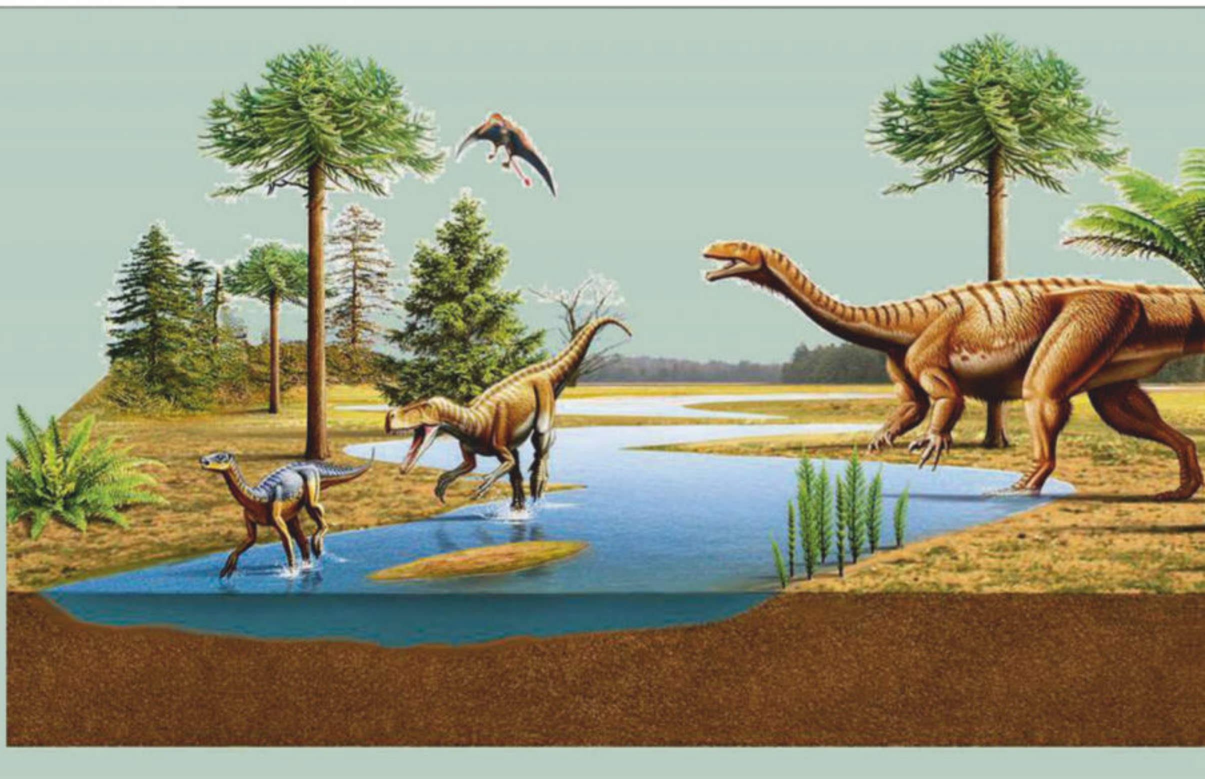
A SURPRISE DISCOVERY

I looked closer. The brown stuff was hair, and there was a spinal column running down the middle. That's when I understood: I was looking at a fossil mammal – a distant cousin of ours, which lived alongside the feathered dinosaurs in the Mesozoic Era, more than 125 million years ago. (The Mesozoic Era ran from about 252-66 million years ago and includes the Triassic, Jurassic and Cretaceous Periods.)

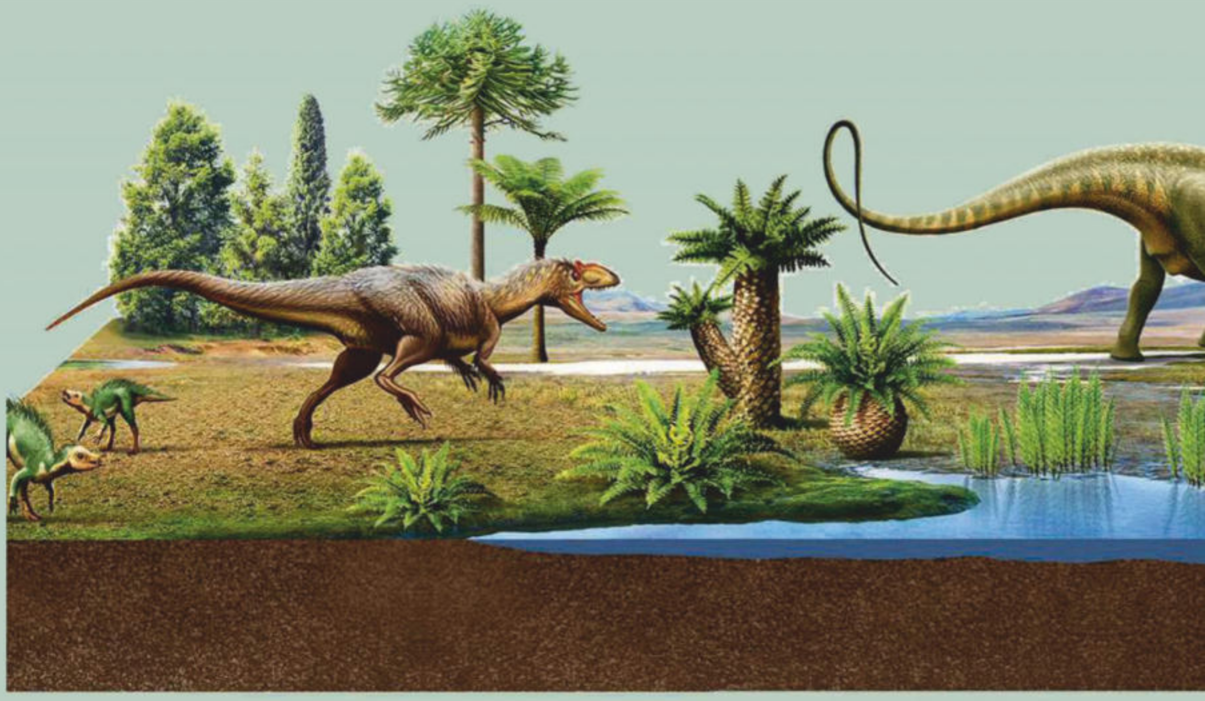


The mysterious, yet-to-be identified fossil revealed to author Steve Brusatte in the back room of a Beipiao apartment

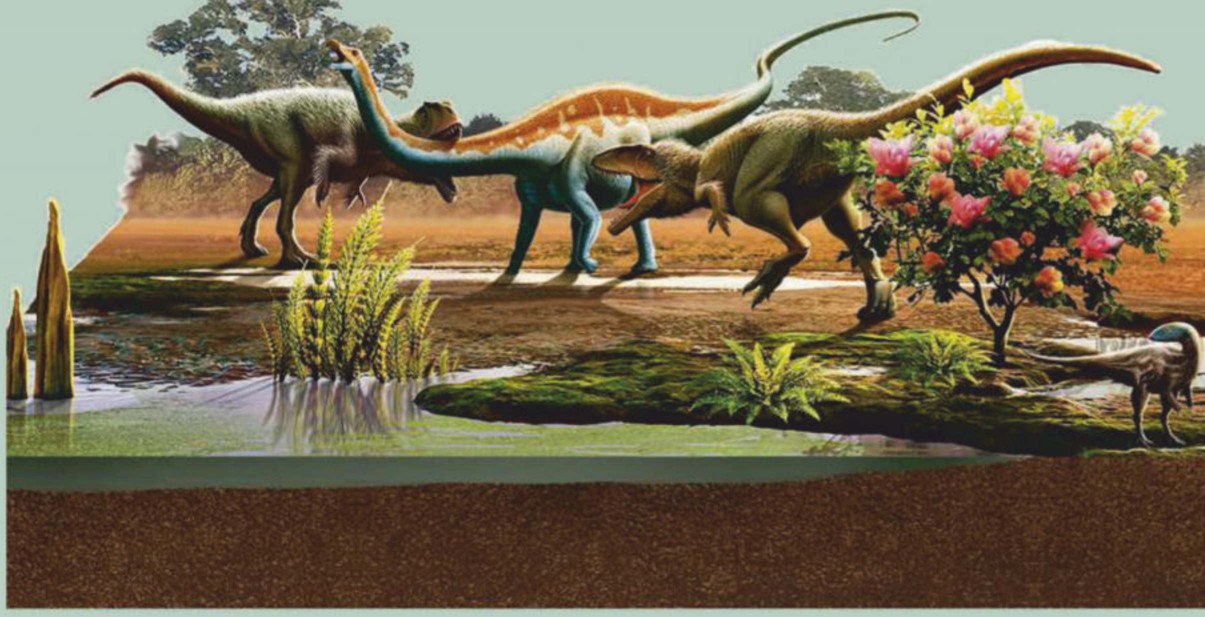
STEVE BRUSATTE, ALAMY



Triassic: Following the Permian extinction, dinosaurs appeared. Mammals also started to evolve.



Jurassic: The warm, wet climate of the Jurassic allowed lush vegetation and dinosaurs to thrive, while mammals scurried around at their feet.



Cretaceous: Flowering plants appeared in the early Cretaceous and rapidly diversified, providing a new food source for mammals.

“THE MAMMAL ANCESTORS GOT SMALLER, MOVED INTO THE SHADOWS, AND MANAGED TO ENDURE THE TERRIBLE EXTINCTION”

This particular fossil has yet to be described, and as far as I know, it is still gathering dust in that non-descript apartment in Beipiao. Maybe it’s a new species, or maybe it’s not, because over the past 25 years more than two dozen fossil mammal species have been found in the Jurassic and Cretaceous rocks of China. Like the feathered dinosaurs, they were buried by volcanic ash and sludge, hence their abundance and pristine preservation. And, like the feathered dinosaurs, they are helping palaeontologists understand how a major group of modern animals – our own group – originated and evolved.

MAKING A MAMMAL

Mammals are unique among modern animals. Among other things, all mammals – from hamsters to humans – have hair, big brains, keen senses of smell and hearing, and differentiated teeth (incisors, canines, premolars, and molars). We nourish our young with milk, are warm-blooded, grow fast, walk upright with our limbs underneath our bodies, chew our food with our complex molars, and are wizards at hearing high-frequency sounds via our chain of tiny middle ear bones and coiled cochlea.

These features, which together define the mammal ‘body plan’, did not evolve all at once. Instead, they developed piecemeal over tens of millions of years, beginning about 325 million years ago when the mammal lineage diverged from the reptiles. The mammal line – known as synapsids – came to dominate the Permian Period (299-252 million years ago), when all land was conjoined into the supercontinent Pangaea. While some synapsids like the predatory gorgonopsians topped the food chain, another synapsid group, called the cynodonts, got smaller, moved into the shadows, and managed to endure the terrible extinction at the end of Permian that extinguished up to 95 per cent of all life. These cynodonts became the immediate ancestors of mammals.

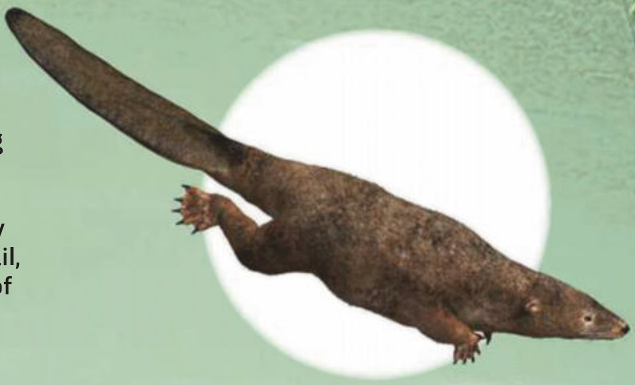
New fossils, combined with cutting-edge analytical techniques, are revealing how mammals emerged from their cynodont ancestors during the ensuing Triassic Period. At first, these near-mammals were still quite reptilian in their biology and behaviour. A stunning discovery of a fossilised mother *Kayentatherium* and more than three dozen offspring, described in 2018 by Eva Hoffman of the American Museum of Natural History, shows that these hairy, dog-sized creatures still had large clutch sizes and small brains. Over time, however, they began to grow more rapidly. They developed bigger brains with a novel region called the neocortex for processing sensory information and rearranged their jaw-closing muscles for more powerful bites.

Meanwhile, these proto-mammals were getting even smaller. This had profound effects on their biology, as shown by two recent studies led by Dr Bhart-Anjan Bhullar of Yale University and Dr Stephan Lautenschlager of the University of Birmingham. They used computer animations and lab comparisons to study the differences between proto-mammals and modern mammals. As mammal antecedents were shrinking in size, the dentary bone of the lower jaw became the dominant jaw muscle attachment site. It seems like a minor tweak, but it had major ramifications, freeing other jaw bones to morph into middle ear bones that could better hear high-frequency sounds, and permitting a new type of rotational jaw movement for more efficient chewing. It is at this point that we can say true mammals emerged. ▶

THE MAIN MAMMALS

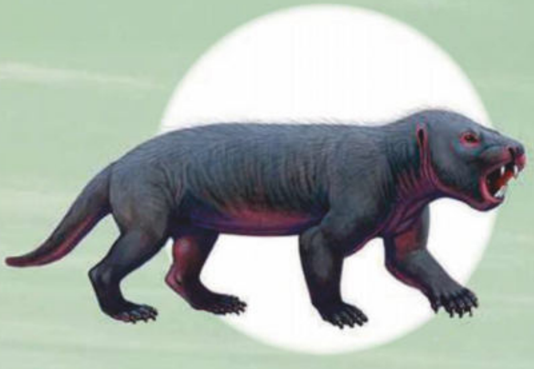
Here are some of the key animals that help paint a picture of how modern mammals evolved

Castorocauda



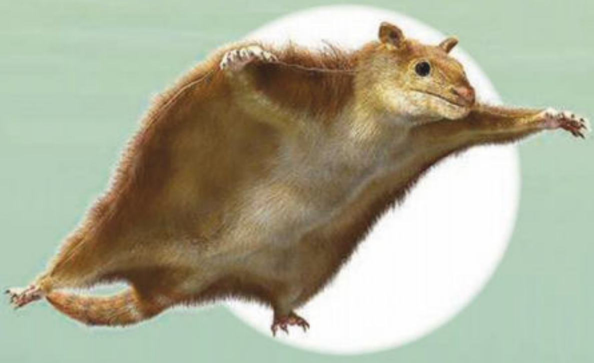
SIZE: 500-800 grams, 43-50 centimetres long
ORIGIN: Inner Mongolia, Middle-Late Jurassic, around 166-157 million years ago
FACTS: Adapted for life in the water, this early mammal had paddle-like limbs, a flattened tail, and specialised teeth for eating fish. It's one of the largest known Jurassic mammals, and although it somewhat resembles a modern beaver or platypus, it's not closely related.

Kayentatherium



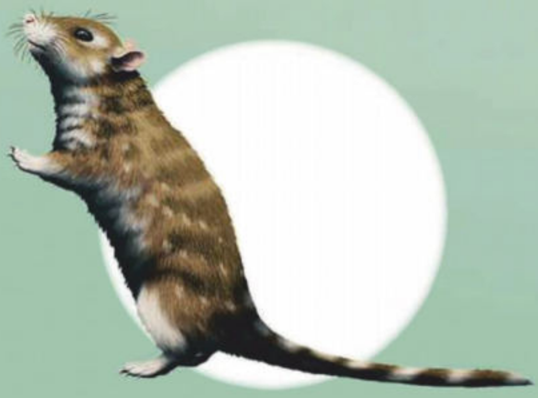
SIZE: Equivalent to a large cat or mid-sized dog
ORIGIN: Southwestern USA, Early Jurassic, around 200-183 million years ago
FACTS: One of the closest relatives of true mammals. They had at least some hair, walked upright, and had a high metabolism.

Volaticotherium



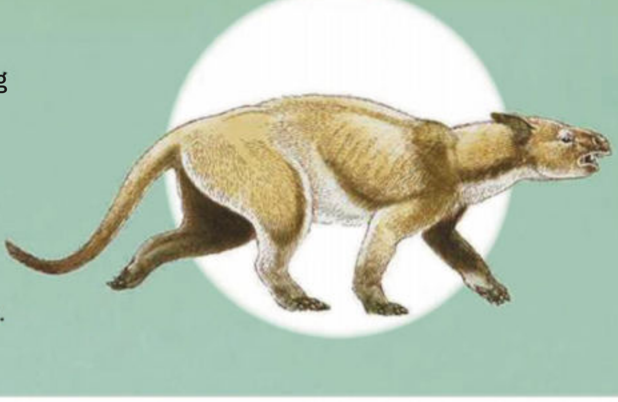
SIZE: 70 grams, 12-14 centimetres long
ORIGIN: Inner Mongolia, Middle-Late Jurassic, around 166-157 million years ago
FACTS: With its skin membrane (patagium) stretching between its body and limbs, *Volaticotherium* could have glided between trees. When it was discovered in 2006, it was the oldest known fossil of a flying mammal.

Litovoi



SIZE: 160 grams, 15-20 centimetres long
ORIGIN: Romania, Late Cretaceous, around 66-69 million years ago
FACTS: *Litovoi* is a multituberculate, an extinct group that thrived in the Cretaceous, survived the asteroid impact, then wasted away to extinction about 35 million years ago. It had one of the smallest brains, proportional to body size, ever for a mammal.

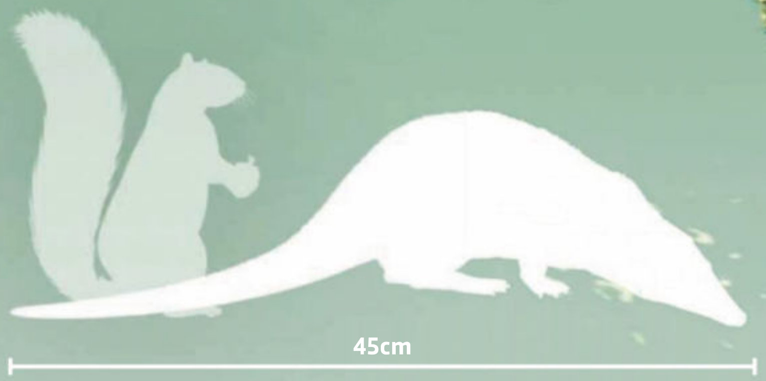
Periptychus



SIZE: 20 kilograms, size of a medium-to-large dog
ORIGIN: Southwestern USA, Early Paleocene, around 63.3-61.7 million years ago
FACTS: *Periptychus* is a 'condylarth', a member of a cluster of primitive hoofed mammals that proliferated after the dinosaur extinction. It had robust teeth to eat roots, stems and other tough plants, and a stout skeleton well-suited for moving on land and navigating forest vegetation.

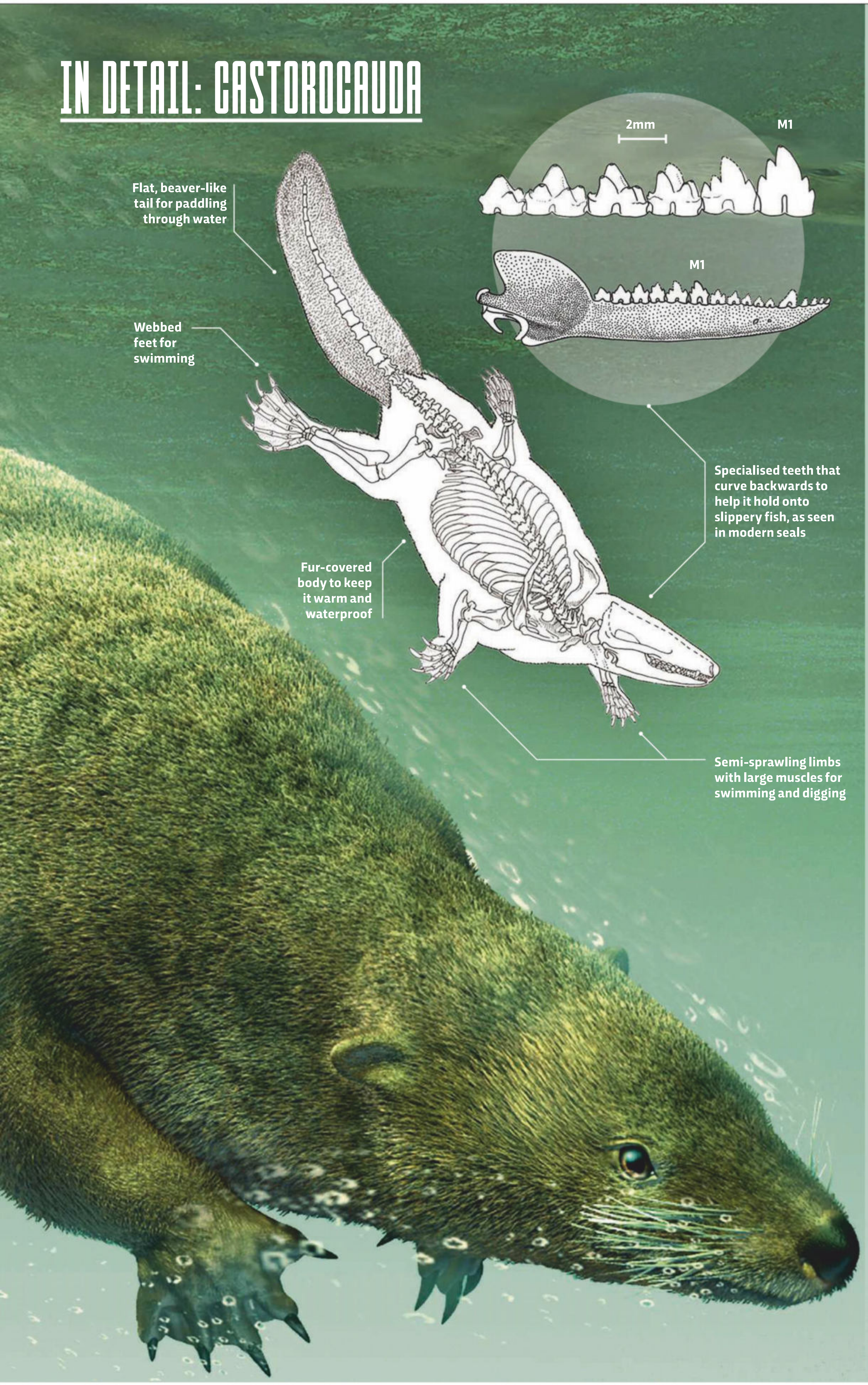
ALAMY X2, CERI THOMAS/NIX DRAWS STUFF, MASATO HATTORI X2, AAAS SCIENCE

Size isn't everything



Although *Castorocauda* is relatively small by today's standards – it was about the size of a grey squirrel – it is one of the largest known Jurassic mammals to be discovered to date

IN DETAIL: CASTOROCAUDA



Flat, beaver-like tail for paddling through water

Webbed feet for swimming

Fur-covered body to keep it warm and waterproof

Specialised teeth that curve backwards to help it hold onto slippery fish, as seen in modern seals

Semi-sprawling limbs with large muscles for swimming and digging

A BRIEF HISTORY OF MAMMALS

CARBONIFEROUS PERIOD
325 MILLION YEARS AGO
The mammal lineage – synapsids – diverged from the reptile lineage, diapsids.

PERMIAN PERIOD
299-252 MILLION YEARS AGO
Synapsids proliferated. Early synapsids called pelycosaurs were replaced by synapsids called therapsids, who held their limbs underneath the body rather than in a reptile-like sprawl.

END-PERMIAN EXTINCTION
252 MILLION YEARS AGO
Synapsids were decimated but some species survived, including mammal ancestors with hair and fast metabolisms – the cynodonts.

TRIASSIC PERIOD
252-201 MILLION YEARS AGO
True mammals evolved, including the monotremes, marsupials and placentals.

MIDDLE JURASSIC
174-164 MILLION YEARS AGO:
Jaws, teeth and ears rapidly evolved to adapt to changing environments.

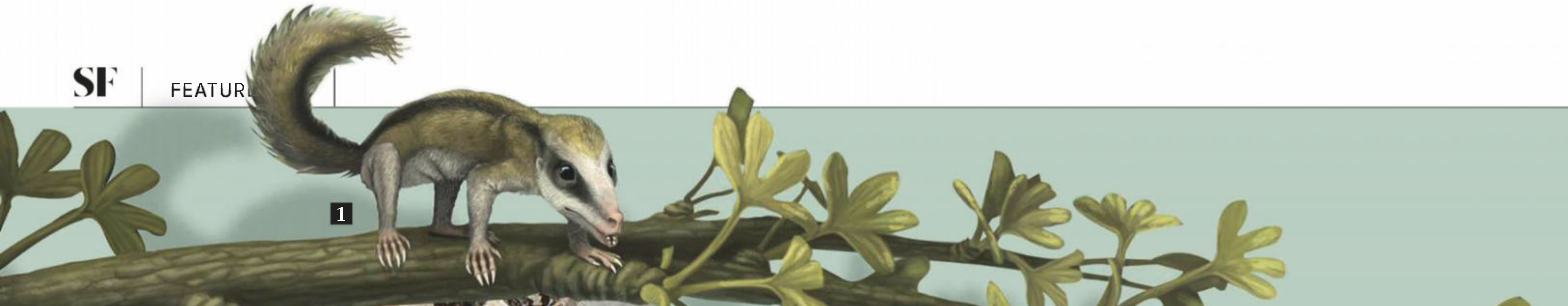
EARLY CRETACEOUS
130-122 MILLION YEARS AGO
Diverse communities of mammals lived alongside feathered dinosaurs in China. Ecosystems were occasionally buried by volcanic eruptions, producing fossils.

CRETACEOUS PERIOD
145-66 MILLION YEARS AGO
Flowering plants originated and evolved rapidly alongside their insect pollinators, providing new food sources for mammals.

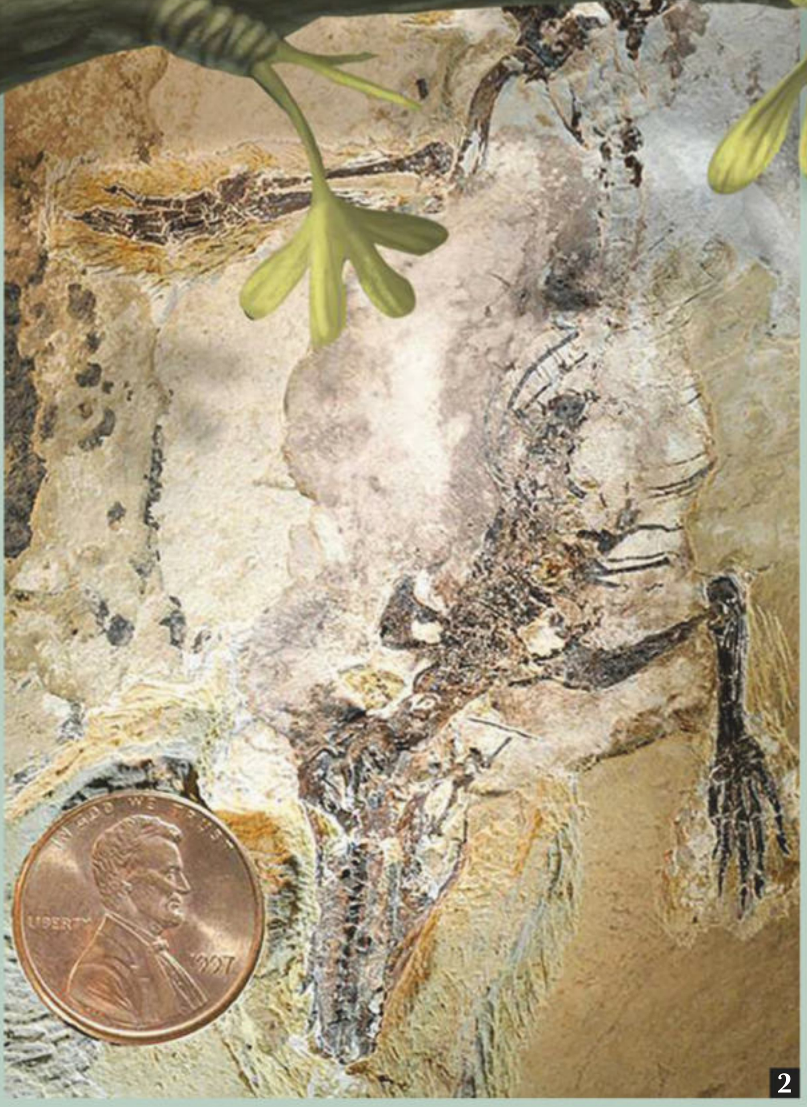
END-CRETACEOUS EXTINCTION
66 MILLION YEARS AGO
An asteroid hit Earth, killing the dinosaurs and many mammals. Placentals survived.

PALEOCENE EPOCH
66-56 MILLION YEARS AGO
The surviving placentals got bigger, developed a variety of diets and locomotory styles, and spread globally.

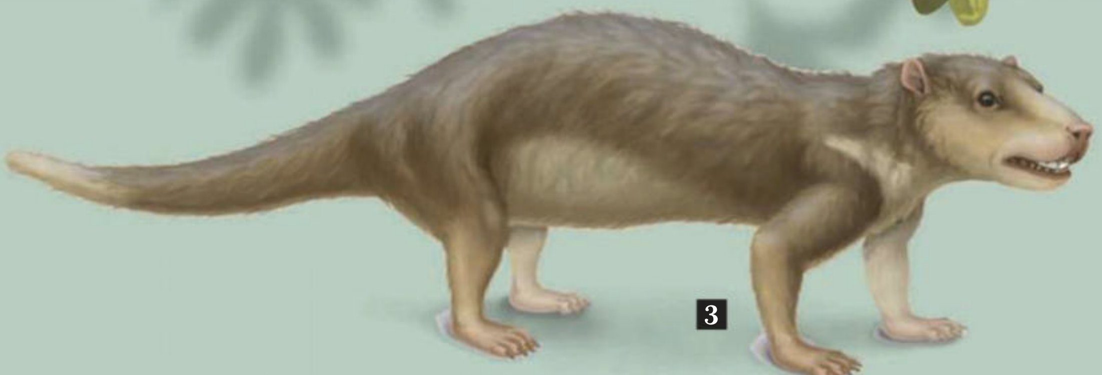
PALEOCENE-EOCENE THERMAL MAXIMUM
56 MILLION YEARS AGO
Sudden global warming causes mammals to diversify. Early relatives of bats, whales and elephants emerge.



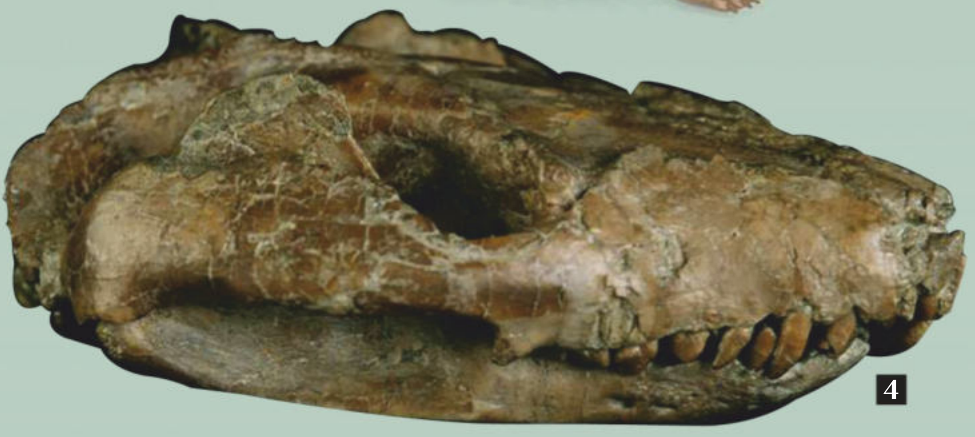
1 Skeletal features of *Agilodocodon* suggest it was an agile, active and arboreal mammal



2 This tiny, fossilised *Agilodocodon scansorius* has been preserved with fur and claws intact



3 One of the largest known Mesozoic mammals, *Repenomamus* could eat baby dinosaurs



4 A well-preserved skull of *Repenomamus robustus* from the early Cretaceous

DIVERSIFY AND THRIVE

Later in the Mesozoic Era, after the extinction at the end of the Triassic Period that ushered in the Jurassic Period, mammals really came into their own. Until fairly recently, it was said that mammals of this age were all tiny, boring, unsophisticated D-list actors in a dinosaur blockbuster. We now know, thanks mostly to the wealth of new fossils from China, that this is false.

Mesozoic mammals were small, that much is true. No known species was bigger than a badger, probably because dinosaurs already dominated the larger-sized niches. But the Jurassic and Cretaceous mammals became masters at surviving underfoot, diversifying into a remarkable array of species and ecologies. There were tree-climbers like *Agilodocodon*; diggers like *Docofossor* that resembled moles; web-footed and beaver-tailed swimmers like *Castorocauda*; and vermin like *Volaticotherium* and *Vilevolodon* that glided between trees on their wings of skin. All of these mammals have been discovered during the last 15 years.

These different mammal species ate a wide variety of foods. Some, like the wolverine-sized *Repenomamus,* used their sharp teeth to devour baby dinosaurs, as recorded by a fossilised last meal in the stomach of one skeleton. Many others, however, started to specialise in two other food types: insects and plants. They were simply taking advantage of what nature had to offer. During the Cretaceous, flowering plants entered the scene and diversified alongside their insect pollinators in an evolutionary waltz. To feast on the insect bounty, some mammals evolved a new type of molar tooth, with a series of cusps that formed a mortar and pestle for crushing and grinding.

This special tooth – a tribosphenic molar – is a signature of two mammal groups that still survive today: the marsupials (whose minuscule babies develop in a pouch) and placentals (our group, which gives live birth to well-developed young). Both groups, along with the third surviving mammal lineage (the egg-laying monotremes), got their start in the Mesozoic. But they weren't

> “A 10KM ASTEROID, SPEEDING FASTER THAN A JET AIRLINER, SMASHED INTO THE EARTH WITH THE FORCE OF OVER A BILLION NUCLEAR BOMBS”

exactly dominant. They shared ecosystems with a panoply of other families that flourished and then went extinct. Many of these, like the buck-toothed multituberculates, were extraordinarily successful. Some multituberculates developed saw-blade premolars and intricate molars to cut and grind plants, whereas others like the Romanian species *Litovoi*, found by palaeontologist Mátyás Vremir and described in 2018, shrunk its brain but evolved super-keen olfaction to adapt to its latest Cretaceous island habitat.

THE END OF AN ERA (LITERALLY)

If you were there 66 million years ago, on the final day of the Cretaceous, you probably would have heard various mammals scurrying through the underbrush… if you weren’t too focused on trying to avoid *Tyrannosaurus rex*, that is. Some of those mammals might have been primitive placentals, but these were still rare, outnumbered by multituberculates and early marsupials. Then, in a moment, everything changed. A 10km-wide asteroid, speeding faster than a jet airliner, smashed into the Earth with the force of over a billion nuclear bombs. Instantaneous tsunamis, wildfires and earthquakes gave way to nuclear winter and longer-term global warming. Dinosaurs like *T. rex* and *Triceratops* couldn’t cope, and all bar a few feathered-and-winged fliers went extinct.

Mammals were one of the great survivors of this mass extinction. The story, however, isn’t as simple as often told. Many mammals died too, including several of the Mesozoic groups with non-tribosphenic teeth, and most marsupials, which came perilously close to annihilation.

Years of fieldwork in the western United States, led by Dr William Clemens of the University of California and Dr Gregory Wilson of the University of Washington, has clarified what happened: larger mammals and those with more specialist diets perished alongside the dinosaurs, whereas smaller mammals with flexible, omnivorous diets had a better chance of surviving. Among these were the placentals.

LIFE FINDS A WAY

Within a few hundred thousand years of the asteroid’s fury, the Paleogene Period was in full swing. Ecosystems had recovered and placental mammals were booming, with some species now nearly as large as cows. I’ve spent several years collecting their fossils in the San Juan Basin badlands of New Mexico, with my colleague Dr Thomas Williamson of the New Mexico Museum of Natural History and our former PhD student Sarah Shelley, now at the Carnegie Museum of Natural History. These mammals seem a little strange: they are stocky, their skeletons look quite archaic, and scans published earlier this year by our colleague Dr Ornella Bertrand of the University of Edinburgh show that they had smaller brains than today’s placentals.

In effect, these New Mexico mammals – species like *Chriacus* and *Periptychus* – were placental pioneers. They were the groups that survived the extinction, got bigger and more diverse in a dinosaur-free world, and set the stage for today’s 6,000+ species. Among them we find the precursors of horses and deer, and of primates – our very own ancestors – beginning to carve out a life swinging from the trees, before eventually coming down, rearing up on our hindlimbs, growing bigger brains, and marching towards civilisation. **SF**

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by **DR STEVE BRUSATTE** *(@SteveBrusatte)*
Steve is a palaeontologist at the University of Edinburgh and the author of The Rise And Fall Of The Dinosaurs *(£9.99, Picador). He is currently writing a book on fossil mammal evolution.*

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Q&A

YOUR QUESTIONS ANSWERED

... IS THE SEVEN-YEAR ITCH A REAL THING?
... HOW DO I FIND THE NORTH STAR?
... WHICH BODY PART EVOLVED MOST RECENTLY?
... WHY ARE WE SO OBSESSED WITH TRUE CRIME?
... WHY DO BLACKBIRDS DIVE IN FRONT OF MY CAR?
... WHY DO ANIMALS HAVE DIFFERENT PUPIL SHAPES?
... CAN I GET CORONAVIRUS TWICE?
... CAN I CATCH CORONAVIRUS FROM A PARCEL?
... WHAT IS VIRAL LOAD?
... CAN MY PET GET CORONAVIRUS?

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PROF ALICE GREGORY Psychologist, sleep expert

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PROF ROBERT MATTHEWS Physicist, science writer

ILLUSTRATION: DANIEL BRIGHT

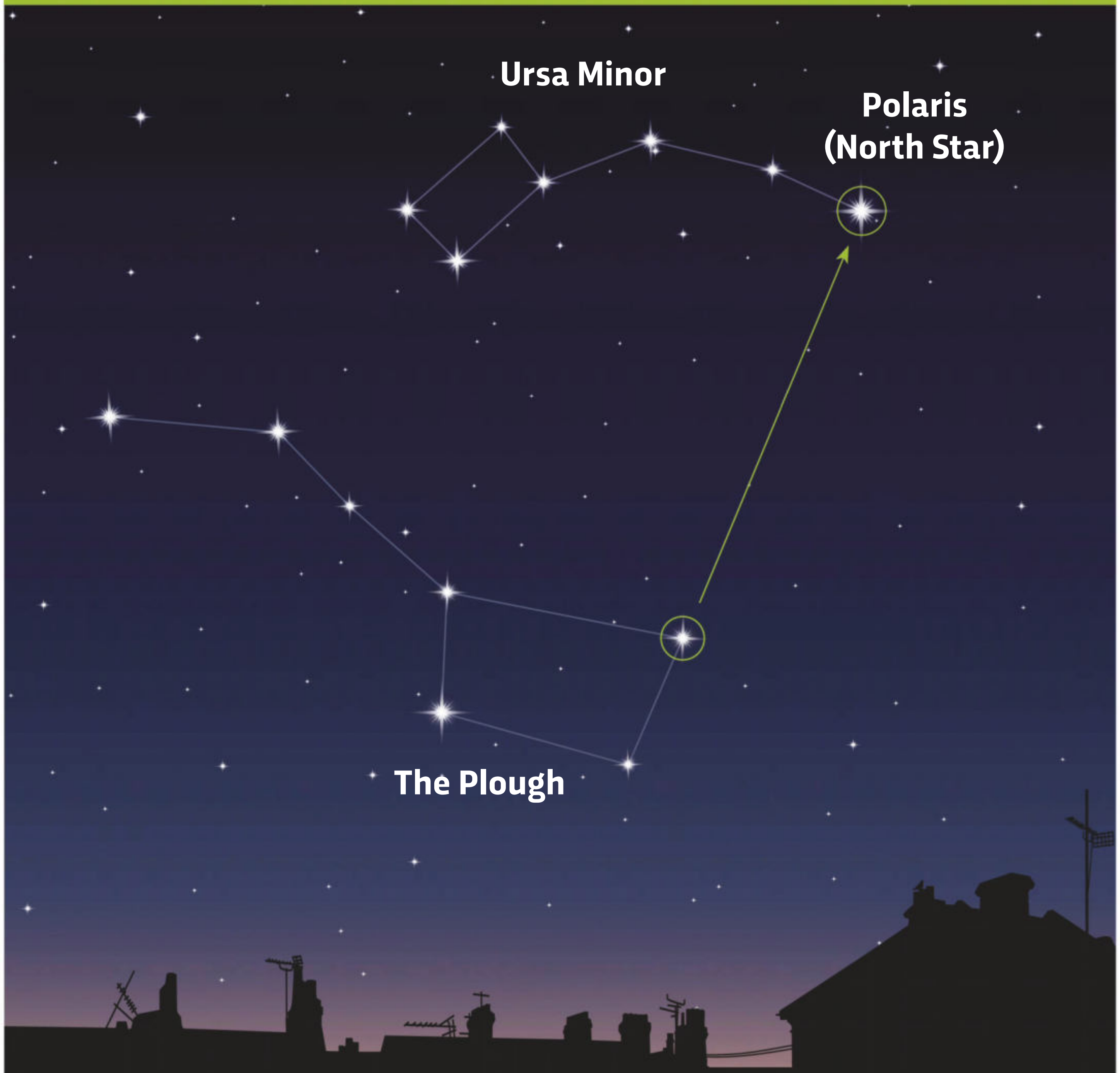
SHAUNA DOWNS

I'VE BEEN HAPPILY MARRIED FOR SIX YEARS, BUT MY FRIENDS ARE TEASING ME ABOUT THE 'SEVEN-YEAR ITCH'. IS IT A REAL THING?

First of all, congratulations on achieving six years of happy marriage: you already seem to be doing better than the average couple! Consider the findings from a 1999 study at Wright State University in Ohio, US, that involved hundreds of newlyweds completing annual psychological tests over the first 10 years of their marriage. The couples' marital satisfaction tended to drop off sharply over the first four years, then to stabilise for a while, and finally to begin another descent after seven years – that last result apparently supporting the folk notion of a 'seven-year itch'. Of course, these are averaged figures and they mask a significant degree of variability.

You can take heart from another US study from 2012 which found that – as you might expect – different married couples have different trajectories of happiness, and at least some manage to maintain their marital bliss for years. Generally, much of it comes down to what you and your partner bring to the marital equation – if you're both emotionally resilient, you problem-solve together and you're attuned to each other's needs, you're more likely to find lasting happiness (if you have kids, how well you adapt to parenting also seems to be a major factor). To help things along, you could consider seeking out new things to do with your spouse – a body of research suggests that continuing to share in 'self-expanding' activities, such as new hobbies or trips to unfamiliar places, can reignite the passion you enjoyed earlier in your marriage. ***CJ***

ASTRONOMY FOR BEGINNERS



HOW DO I FIND THE NORTH STAR?

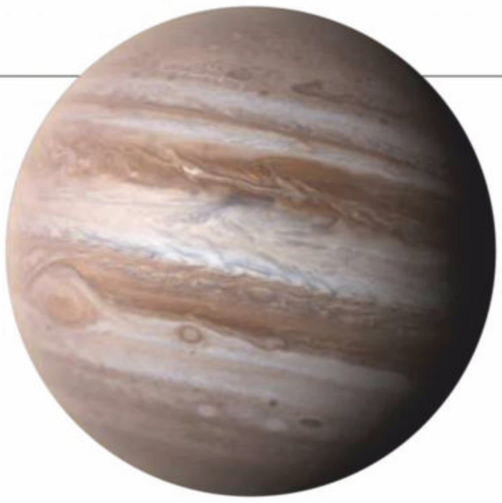
WHEN: ALL YEAR ROUND, NORTHERN HEMISPHERE

As the seasons change, so do the stars visible in the sky. But from the northern hemisphere, one star is constant. The North Star, or Polaris to give it its official name, is so-called because it is positioned almost exactly above our North Pole, in line with the Earth's rotational axis. As the Earth rotates, Polaris stays almost fixed, while the other stars appear to rotate around it. Polaris is actually three stars, but they're locked in a mutual orbit and appear to us as one star in the constellation Ursa Minor (Little Bear). The largest of these is a yellow supergiant with over five times the mass and more than 1,000 times the brightness of our Sun. It's roughly 400 light-years away, but is still around the 50th brightest star in the night sky.

Wherever you are in the northern hemisphere, you'll be able to see Polaris. The constellation Ursa Major (Great Bear) offers the easiest way to find it. This is home to the famous, pan-shaped pattern of stars ('asterism') known as 'the Plough' in the UK and the 'Big Dipper' in the US. Locate this asterism by looking for the four bright stars that mark the pan's 'bowl', and the three stars that mark the 'handle'.

Now imagine a straight line passing up through the two stars on the pan that are furthest from the handle. If you continue this line until you find a distinctively bright star, you've found the North Star!

Earth's axis is tilted, and it moves around like a gyroscope in a slow process called precession. This means that in a couple of thousand years' time, Polaris will no longer be the North Star. That honour will instead go to Gamma Cephei, a binary star system in the constellation Cepheus. ***AB***



SHANNON RIPSHER

HOW BIG WOULD JUPITER BE IF IT WERE STRIPPED OF ALL ITS GASES?

Thanks to NASA's Juno mission, we now have a few clues as to what Jupiter's internal structure looks like. At its centre, extending out by up to 30 per cent of the planet's radius, is a dense, liquid core made of ionised ('metallic') hydrogen and helium, mixed with dissolved heavier elements. The pressure and temperature inside Jupiter drop off as you get further from the centre. This means the liquid interior eventually gives way to a gaseous atmosphere (also mostly hydrogen and helium). The depth of this liquid/gas boundary is not well defined, but Jupiter is probably fully liquid a few thousand kilometres below the planet's cloud tops. So, even if we stripped Jupiter of its gases, it would still be bigger than Saturn. ***AGu***

LUCA BLACKWELL

WHICH PART OF THE HUMAN BODY EVOLVED MOST RECENTLY?

Evolution doesn't just hand out useful traits such as opposable thumbs or colour vision like lottery prizes. Natural selection is constantly tinkering, and no part of our body is more 'recent' than another. But some are changing faster. One of the fastest movers is the human jaw, which has been steadily shrinking over the last 10,000 years, as the invention of agriculture and cooking gave us softer foods that need less chewing. ***LV***

COLIN SWAIN

WHY DO BLACKBIRDS ALWAYS DIVE IN FRONT OF MY CAR?

A speeding car feels like a threat: birds don't understand that cars won't leave the road to chase them down. Some species will escape upwards, but gaining altitude is difficult to do quickly. Species that live in hedgerows, like the blackbird, prefer to dive close to the ground where they can easily reach cover and hide. In springtime, this behaviour could also be the bird's way of protecting its nest, by distracting any would-be predator. ***LV***

CROWDSCIENCE

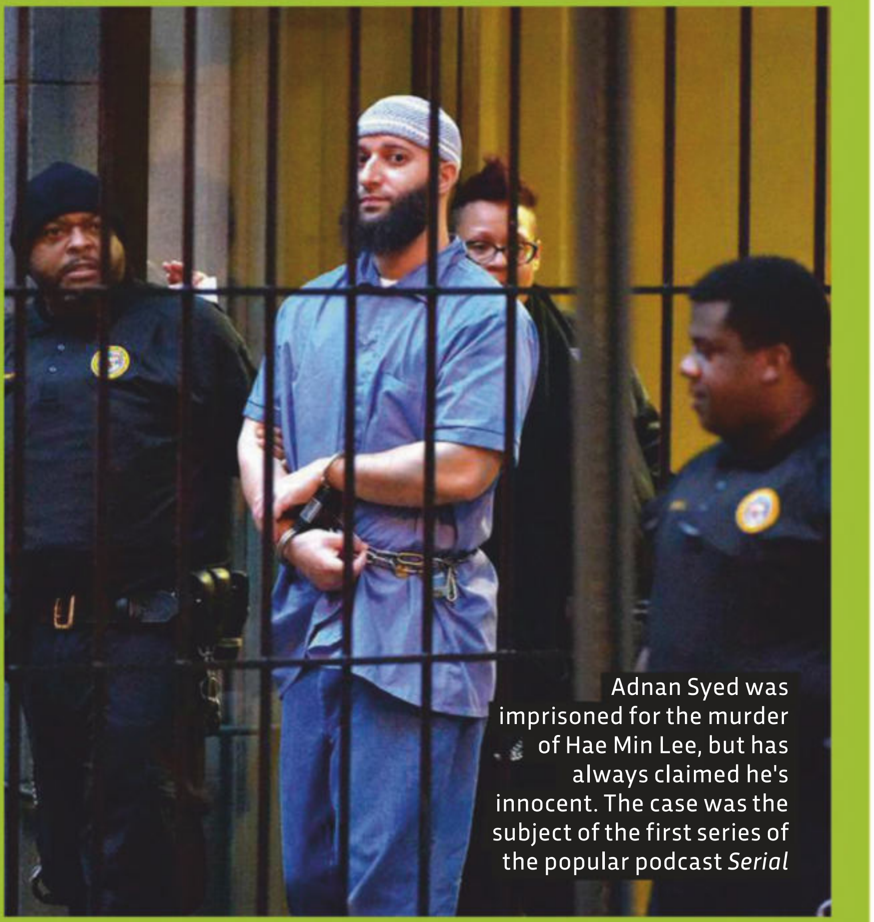
Every week on *BBC World Service*, *CrowdScience* answers listeners' questions on life, Earth and the Universe. For more on the psychology of crime, listen to *Why are we obsessed with crime?* **bit.ly/crowd_crime**

WHY ARE WE SO OBSESSED WITH TRUE CRIME?

Crime stories seem more popular than ever. Bookshop shelves and TV schedules are heaving with murder mysteries and whodunnits. And the 'true crime' genre has been given a new lease of life in recent years, with smash-hit documentaries such as *Making A Murderer*, *The Jinx* and *The Keepers*. The podcast *Serial* – season one of which investigated a real-life murder – has attracted hundreds of millions of downloads.

Evolutionary psychologists say that we're drawn to these tales because murder, rape and theft have played a significant part in human society since our hunter-gatherer days. It's in our nature to be highly attuned to criminal misdemeanours, and we instinctively want to discover the 'who', 'what', 'when' and 'where' so we can find out what makes criminals tick, and to better protect ourselves and our kin. A 2010 study at the University of Illinois at Urbana-Champaign found that women tend to be drawn towards true crime stories more than men, and that they are most interested in stories that give insight into the killer's motives, that contain information about how victims escaped, and that feature female victims. So this fits with the evolutionary idea – that people are instinctively drawn towards stories where they can identify with the victim and read about tips and strategies for defeating the 'baddies'.

Of course, there are other reasons for why we're drawn to true crime: there's a problem-solving element to many of the cases, for example, and there's the satisfaction of getting lost in a really good story. ***CJ***



Adnan Syed was imprisoned for the murder of Hae Min Lee, but has always claimed he's innocent. The case was the subject of the first series of the popular podcast *Serial*

GETTY IMAGES X2 ILLUSTRATION: DANIEL BRIGHT

HIDDEN FIGURES

ALICE BALL
PIONEERED THE TREATMENT OF LEPROSY

Notorious for its disfiguring effects, leprosy is an infection that has long been associated with social stigma, those afflicted often being forced to live in squalid 'colonies'. Caused by two similar species of bacteria, it's now completely curable using antibiotics. But before the 1940s, the only hope lay with an oil from the seeds of the chaulmoogra tree found in Asia and Africa. While the oil could be effective (we now know it has antimicrobial properties), it was difficult to administer. Its acrid taste often made patients throw up, and if it was injected under the skin, it formed burning blisters instead of being absorbed into the body.

In 1915, a young African-American chemist took up the challenge. Born in Seattle in 1892, Alice Ball was already recognised as a gifted research chemist at the College (now University) of Hawaii, becoming the first woman and first African-American to earn a graduate degree there. She quickly found a way of making the oil less viscous and more soluble in water, and thus suitable for injection.

By 1918, Ball's breakthrough was allowing people with leprosy to recover and return to their families. Tragically, however, she never lived to see the success of her work: in 1916 she died, possibly after mistakenly inhaling chlorine gas during a class demonstration. Another chemist continued Ball's work without crediting her, denying her recognition for decade. *RM*

TOP 10

FASTEST TRAINS

ALL ABOARD THE SPEEDIEST TRAINS IN THE WORLD.

1

Shanghai Maglev
Speed: 430km/h (267mph)
Country: China

2

Harmony CRH 380A
Speed: 380km/h (236mph)
Country: China

3

Shinkansen H5
Speed: 360km/h (224mph)
Country: Japan

4

AGV Italo
Speed: 359km/h (223mph)
Country: Italy

5

Siemens Velaro E
Speed: 349km/h (217mph)
Country: Spain

6

Talgo 350 SRO
Speed: 349km/h (217mph)
Country: Saudi Arabia

7

ICE 3
Speed: 330km/h (205mph)
Country: Germany

8

KTX-Sancheon
Speed: 330km/h (205mph)
Country: South Korea

9

Eurostar e320
Speed: 322km/h (200mph)
Country: Europe & UK

10

SNCF TGV Duplex
Speed: 320km/h (199mph)
Country: France

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QUESTION OF THE MONTH

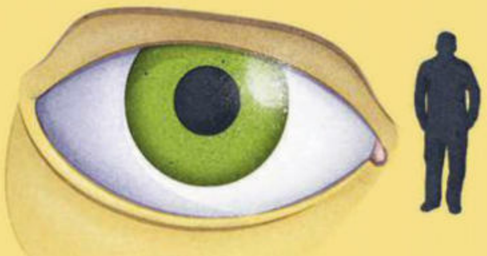
DAVID COLLINS

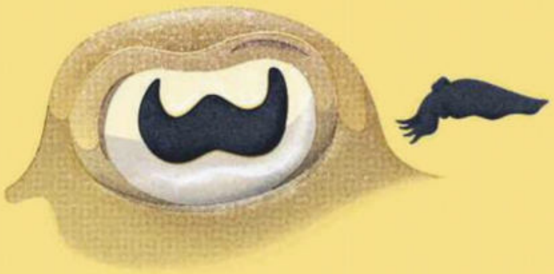
WHY DO ANIMAL PUPILS COME IN DIFFERENT SHAPES?

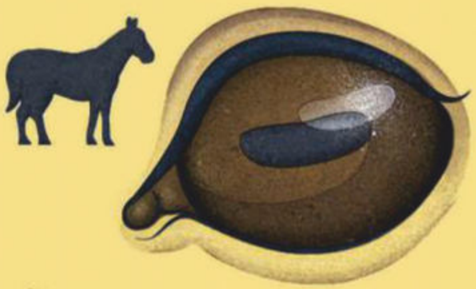
The pupil is the gap in the eye's iris that allows light through to the retina. The muscles of the iris vary the pupil's size, altering the amount of light that can get through. Our pupils are circular because the muscles are arranged in a ring that contracts evenly towards the centre. This has the advantage of giving even focus across the entire field of view, but circular pupils aren't able to constrict as tightly as other pupil shapes. Animals that hunt – or are hunted – at night need large, sensitive eyes that would be overwhelmed in bright daylight, so they have evolved an extra set of muscles to pull the pupil into a narrow slit shape during the day.

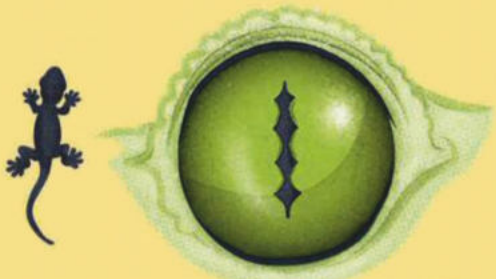
A 2015 study at the University of California, Berkeley, concluded that the evolutionary choice between vertical and horizontal slit pupils comes down to whether you are predator or prey. Predatory animals with vertical slit pupils, like cats and many snakes, can maintain sharp focus across the horizontal field of view and more accurately judge distance to their prey. Horizontal slit pupils, on the other hand, sacrifice image sharpness at the left and right edges in return for wider peripheral vision. This gives prey animals such as horses and sheep a better chance of spotting predators.

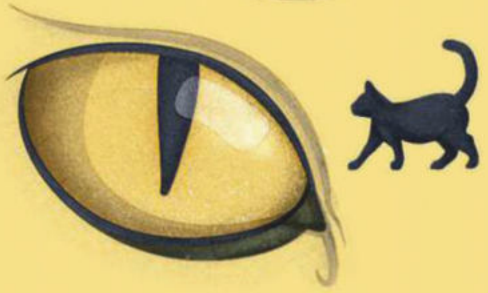
Some animals have evolved even more elaborate shapes. Cuttlefish have a W-shaped pupil that helps to balance the bright light from above with the darker levels below. Some geckos have pupils that constrict to resemble a vertical string of pearls. This may have evolved to allow them to judge distance even without focusing both eyes in the same direction, by comparing the blurring at different pupil apertures. ***LV***











WINNER

David wins Red5 GPS Falcon FPV drone from Menkind, worth £99. The drone is perfect for beginners. It has a flight time of 11 minutes and can take HD video and images from above. You can even plot it a route to follow using its handy onboard GPS.
menkind.co.uk

2

The number of hours a week spent in nature that is linked with feeling healthier and happier, according to a recent study in the journal *Scientific Reports*.

YASMIN HAYES (AGE 13)

WHY DO I ALWAYS COME UP WITH MY BEST IDEAS WHEN I'M TRYING TO GET TO SLEEP?

The transition from wakefulness to sleep is called the 'hypnagogic state', and this is thought, anecdotally, to be associated with creativity. The surrealist artist Salvador Dalí called it the "slumber with a key", and Mary Shelley said that the idea for her novel *Frankenstein* came to her during a "waking dream". There's actually been little scientific research into the link between the hypnagogic state and creativity, but during this state, our mind is free to wander, and this could make us more likely to have spontaneous, creative thoughts. If you fall asleep immediately after this state, you will likely forget your inspirational ideas, so maybe keep a pen and paper by your bedside! ***AGr***

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM** OR TWEET US **@SCIENCEFOCUSQA**

RUSSELL PEARSON

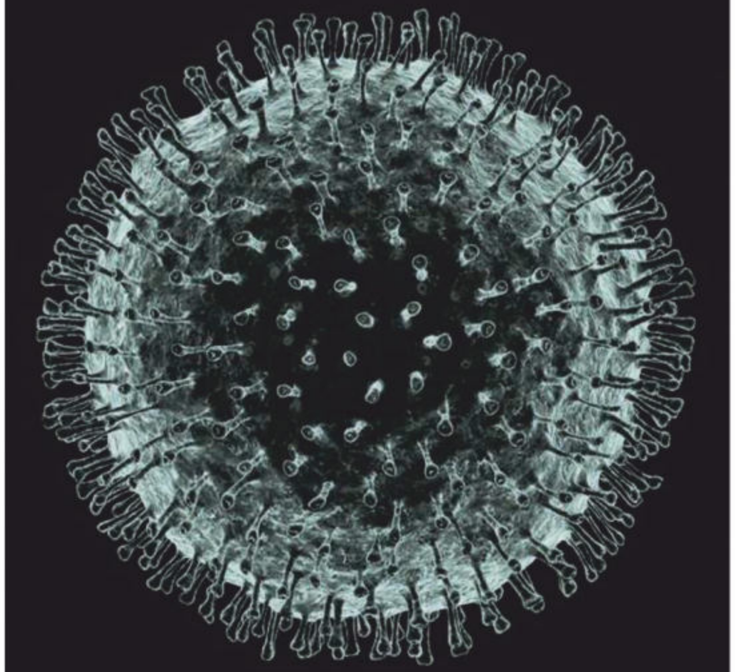
CAN I GET THE CORONAVIRUS TWICE?

There have been a few stories of people apparently being re-infected by the coronavirus SARS-CoV-2. These people reportedly became infected and hospitalised, and then were sent home once they'd tested negative for the virus. Then, days or weeks later, they tested positive again. But this doesn't necessarily mean that they caught the coronavirus twice.

First, during recovery from infection, a person may have such low amounts of the virus in their body that our tests can't accurately detect it. However, their body may still be fighting the virus, and a resurgence of the virus (and symptoms) can occur, resulting in a positive test. In this case, it would just be one protracted infection, not a re-infection.

Second, we know that in most people, the SARS-CoV-2 virus generates a strong immune response. With the related coronavirus SARS-CoV, this response creates an immune memory of the virus that prevents re-infection for one to two years, and it's likely that this is also the case for the new virus. SARS-CoV-2 also has a fairly low mutation rate, which means that it (hopefully) won't change enough that our immune system no longer remembers it (this is what the flu virus does and why we need a new jab every year).

If this all turns out to be true, then it would suggest that re-infections are unlikely. However, SARS-CoV-2 is so new that we won't know for sure until we've found out just how protective our immune response to the virus is, and how long it lasts. ***JR***



HAZEL ROBINSON

CAN MY PET GET THE CORONAVIRUS?

There have been a few cases of dogs and cats testing positive for the COVID-19 after their owner was confirmed as infected. However, in most of these cases, the animals didn't have any symptoms, and it might be that some – or even all – of these animals weren't infected, but had just breathed in contaminated air.

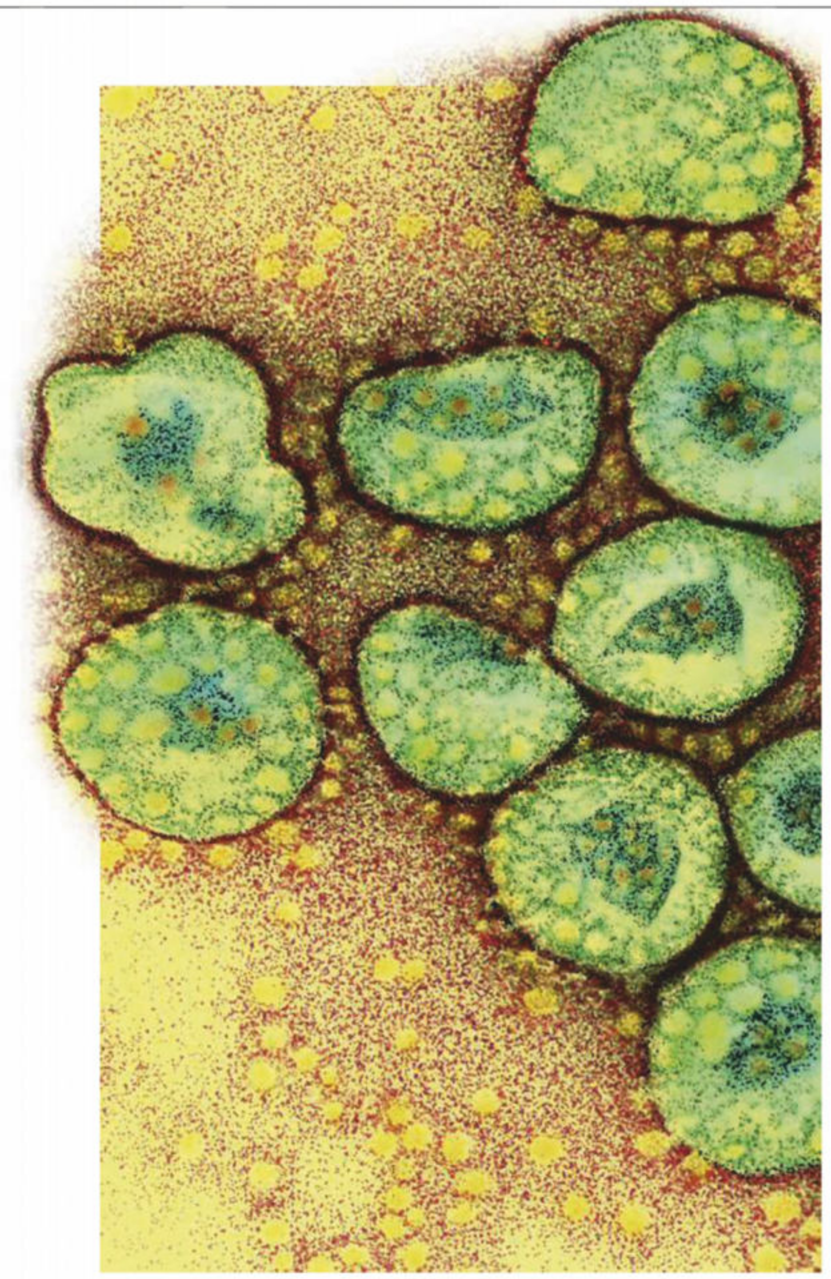
Even if these animals were infected, transmission from human to animal is rare, and there's no evidence that pets play a role in spreading the disease. There are also no reports of the virus passing from pet to human.

That said, pets do pose a small risk of transmission if someone touches an animal that belongs to someone with COVID-19. Because of this, people who have symptoms of COVID-19 are advised to limit their contact with pets and wash their hands before and after interacting with them. For everyone else, keep regularly washing your hands and practise physical distancing, from people as well their pets. ***JR***

YASMIN HAYES

CAN I GET THE CORONAVIRUS FROM A PARCEL?

It's hypothetically possible, but parcels pose a very small risk. A US study found that the coronavirus can survive for up to 24 hours on cardboard (and paper is likely to be similar). So for the parcel to be contaminated, someone with COVID-19 would have had to touch or cough on your parcel within the past day. The chances of this are low, but common sense advice would be to wash your hands with soap and water after opening the parcel, and then again after you've disposed of the packaging – especially if you or anyone else in your household is in one of the vulnerable groups. ***JR***



SAM HARRIS

WHAT IS VIRAL LOAD?

Viral load is simply the amount of virus in the body. This varies in different parts of the body, and can change over time. Recent studies have shown, for example, that the viral load in the lungs of COVID-19 patients is greater than that in the nose. A patient's viral load increases as the virus replicates and disease symptoms get worse, and then decreases as the patient recovers.

The amount of virus that you're exposed to at the beginning of an infection is something different, and this is called the 'infectious dose'. Studies on other viruses such as the flu and SARS have shown that the higher the infectious dose (the more virus you breathe in), the greater your chances of having more severe symptoms. With one small exposure, your immune system may be able to fight off the virus before you get sick, but with repeated small exposures (such as touching your face throughout the day) or one large exposure (an infected person coughing in your face), the virus may grow faster than your body can control. We don't yet know if this link between infectious dose and disease severity holds for COVID-19, but it may do, and that's why it's so important to maintain physical distancing and keep the initial exposure as low as possible. ***JR***

SCIENCE PHOTO LIBRARY X2, GETTY IMAGES, ALAMY ILLUSTRATION: DANIEL BRIGHT

DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

I'VE BEEN STOCKPILING TISSUES FOR THE PANDEMIC, BUT MY OTHER HALF SAYS HANDKERCHIEFS ARE BETTER. WHO'S RIGHT?

You are! First off, handkerchiefs are less hygienic than single-use tissues. When you blow your nose in a handkerchief, you're providing a fresh influx of snot to any germs already there. If these germs are viruses, the protein in your snot can help protect them from drying out; if they're bacteria, the extra moisture can help them to grow.

When you next use your handkerchief, any germs that survived from the previous use are transferred back to your hands, which will contaminate the next door handle you touch. You can do a lot to limit this spread by washing your hands every time you blow your nose, but this isn't always practical. Far more hygienic is to use a tissue and then throw it out.

What's more, handkerchiefs are worse for the planet, too. A 2012 study by environmental consultants Ecosystem Analytics found that the CO_2 emissions and pollution produced during the manufacture of a cotton handkerchief outweighed any savings over its lifetime compared to disposable tissues, even if you kept the same hanky for nine years. Handkerchiefs do have the advantage that you don't have to stockpile them, but that's about all they've got going for them. Still, we wouldn't recommend stockpiling tissues – leave some for others! ***LV***

THE EXPLAINER

HOW TO WORK FROM HOME SUCCESSFULLY

Has the COVID-19 lockdown forced you to work from home? Here are our top tips, according to science, to help you stay happy, healthy and productive over the coming weeks

If you'd been told in January that you'd be able to work from home for months on end – dodging overcrowded trains and office politics in the process – it might have sounded like a start-of-the-year bonus. The reality, of course, is not so enjoyable.

As the world adjusts to the coronavirus pandemic, one of the biggest changes is enforced home-working. Staying motivated, retaining a work-life balance and negotiating video-conference etiquette are just some of the challenges. But science is here to help.

Even before quarantines and social distancing measures became the norm, researchers debated what remote working does to your mental health and productivity. So we conference-called leading psychologists to ask them how best to thrive in the shadow of COVID-19.

DRESS FOR THE JOB YOU STILL HAVE

Fashion doesn't really exist when the world is on lockdown, but psychologists recommend you get dressed for work rather than joining those video calls in your PJs. More than just keeping up appearances, it helps put your brain in work mode.

In a 2012 paper in the *Journal Of Experimental Psychology*, researchers used the term 'enclothed cognition' to describe the way that clothes can affect the wearer's behaviour. In the study, participants who wore a white lab coat performed better in tests of their attention, for example.

If you normally wear a shirt to work, wear one in the home office too. "Get dressed in the morning, make yourself feel like you're going to work," says Prof Cary Cooper, an occupational psychologist at Manchester Business School. "But be comfortable."

Don't skip the shower, either. There's bracing evidence to suggest that a cold shower can boost your mood and attention.

STRUCTURE YOUR DAY LIKE NORMAL

Routine and structure are crucial to making the quarantine period tolerable, and that starts with your sleep. Resist the urge to hit the snooze button. In what was described as the largest sleep study ever conducted, researchers at Canada's Western University found that oversleeping can dampen your cognitive function, just like sleep deprivation can. "Research shows that keeping routines, but with some variation – having different exercises and tasks at different times – is really important," says Dr Jo Daniels, a clinical psychologist at the University of Bath. Do something positive with the time you saved from your commute, such as cooking a healthy lunch or going for a jog.

Then work according to your own circadian rhythms. "Structure your workload depending on whether you're an owl or a lark," says Cooper. "Do the most important work when you feel most energised, unless it has to be done before. If you're a slow starter, doing menial tasks first and important tasks later is maybe the way to go."

You can also create a more effective list of priorities by making a weekly to-do list, rather than a daily one – the truly important jobs will jump out at you.

GETTYY IMAGES X5

PROTECT YOUR MENTAL HEALTH

As if a lethal pandemic wasn't enough to trigger anxiety and depression, research suggests that remote workers can also be prone to bouts of poor mental health. A UN report in 2017 found that remote workers are more likely to experience high stress levels than office workers: emails are misinterpreted, work bleeds into family life and remote workers often clock more hours.

As well as switching off the laptop at the end of the day, make sure you do pleasurable activities for mood elevation, says Daniels. "If you feel yourself becoming anxious, switch to exercise, reading, listening to podcasts, creative pursuits, intellectual pursuits."

Also, take this time to catch up with friends and family and get to know them like never before. "It's important that we stay in touch with people but also that it's not just a touch-base focus on the coronavirus. Actually show interest in the other person," Daniels says.

She adds that if you suffer acute moments of panic or anxiety, practising breathing techniques can help, as can talking about your emotions. Otherwise, try to see the benefits of being at home. "For me, I don't have to travel miles to work every day and that's great."

CREATE BOUNDARIES

Do what you can to physically separate your working space from your living space, especially if you have kids at home. Even the shortest distraction can kill your productivity. Research at Michigan State University found that a three-second interruption can double the number of mistakes you make in your work as your attention gets dragged away to something else.

Don't have kids? Then self-isolate from that other great dependant: your phone. A 2014 study at the University of Southern Maine found that when testing complex tasks, the mere presence of the experimenter's phone (not a participant's) was enough to distract people and lead to lower scores in the test.

SIT NEAR A WINDOW

The field of environmental psychology, which explores our relationship with our immediate surroundings, has lots to teach us about being stuck indoors and creating an office in the home.

"The first thing to think about is where to sit," says Lily Bernheimer, director of Space Works Consulting. She refers to a concept known as 'refuge and prospect', which says that humans are more comfortable sat with our backs to the wall and a view of the door or window. "We believe that we evolved to prefer these settings because these factors could have contributed to our survival by being the safest places we could be."

A view of trees or even a picture of scenery on your wall can help. "If you can find a room with a view of any kind of nature, then this has the ability to reduce blood pressure and the circulation of stress hormones, and it increases the capacity for directed attention, which is the ability to focus."

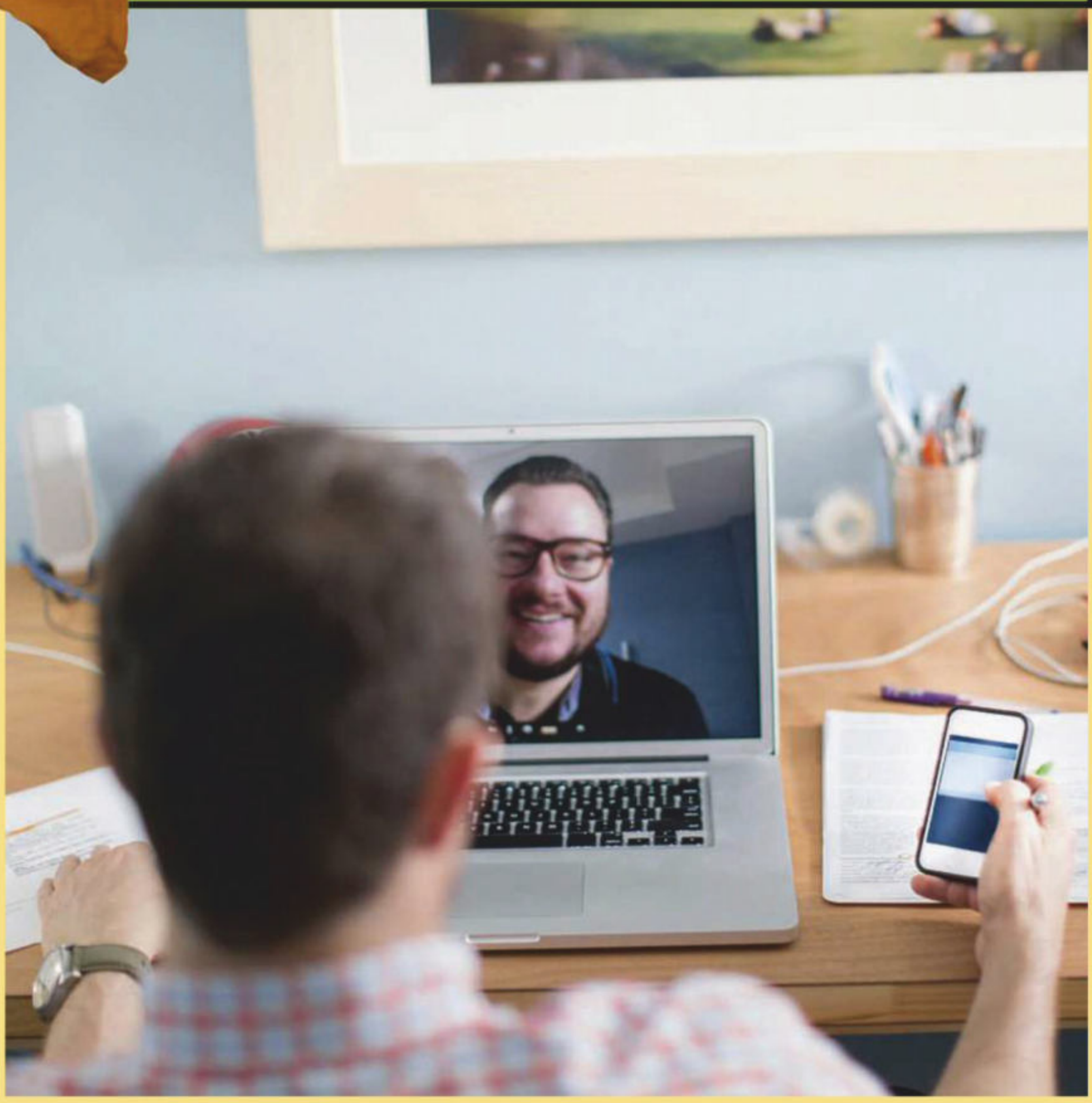
ADJUST THE THERMOSTAT

It's tempting to think that you can hack your productivity by setting light, temperature and other conditions to optimal levels. This is true to an extent, says Bernheimer.

"There are certain benchmarks and types of light that are better for relaxing or concentrating, but what we also find is that holding constant settings throughout the day will not make the best environment for concentration."

She advises you mimic what happens outside, exposing yourself to different kinds of light. "Cooler light [blue-toned] is believed to be better, generally, for concentration, but it's not natural for us to have that cool light throughout the whole course of the day."

The same is true with temperature, noise and air flow: vary them for best results. "There's really interesting research that shows both mildly cold and mildly warm environments increase human metabolism and this counterbalances excess energy intake," Bernheimer says. That's good for the stockpiled Jaffa Cakes as well as your alertness...



ARRANGE A MEETING (OR THREE)

A commonly told joke at the start of the pandemic was that the coronavirus would teach us whether all those meetings could have been emails after all. Excess meetings may have been a bugbear of the pre-COVID-19 workplace, but right now they're essential. And not just for much-needed human contact, Cooper says.

"The individual manager's role is suddenly more important than ever before," he says. "Reassure, motivate and make your team feel secure. Don't just email people. You have to do it eyeball to eyeball." Use technology like Skype, Slack and Zoom, especially when problems arise. Cooper says this will minimise misinterpretations and prevent time-wasting chains of emails that devour your day.

It might also make your team more effective. A 2017 study in the *Journal of Organizational Behavior* found that teams who met regularly for debriefs produced more innovative solutions to problems. Appoint somebody to lead the meeting, review recent work and brainstorm ways of improving.

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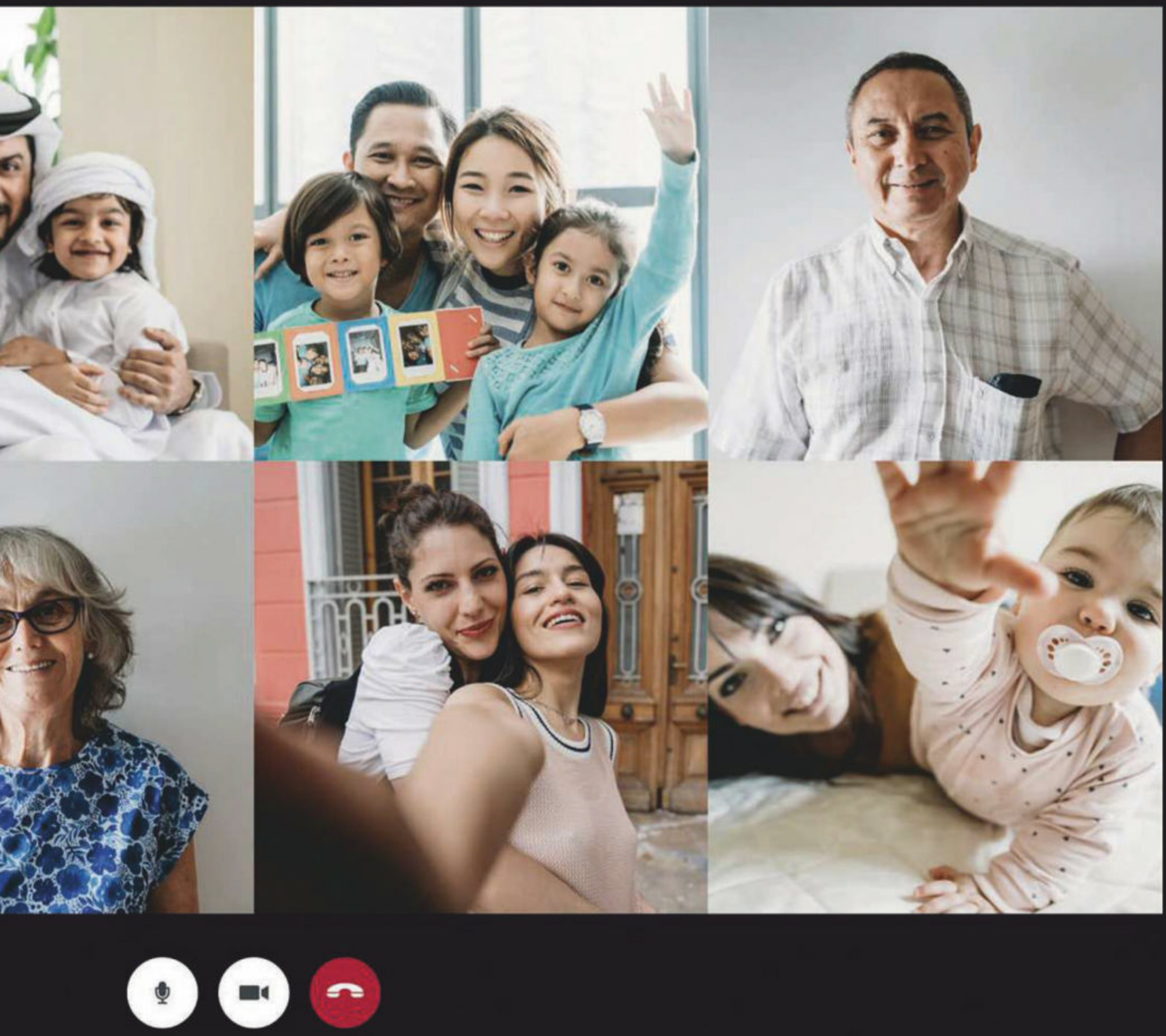


COMBAT LONELINESS

"Remember we're social animals," says Dr Angela Carter, associate fellow at the British Psychological Society. "Part of the reason we go to work is that we love being with other people." Nobody should take the threat of loneliness lightly during the pandemic because it can lead to poor mental and physical health in other areas.

Playing with your pets and video-calling your family are no-brainers, but don't forget about your colleagues, too. "Using virtual spaces to meet up is really good," says Prof Pamela Qualter, a specialist in loneliness research at the University of Manchester. "But there is a temptation to use those just for work meetings."

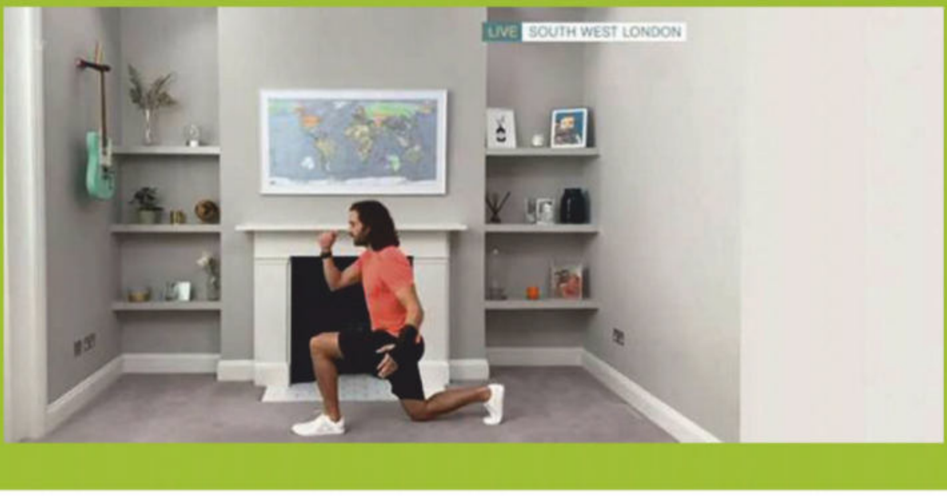
She says that a lot of the time we spend interacting at work is not actually about work (don't tell your boss). "That type of interaction is likely to be what we miss when we are self-isolating. So, I would recommend meeting colleagues or friends online for regular coffee breaks or lunch, so you don't miss out on that type of social interaction."

WORK OUT TO WORK WELL

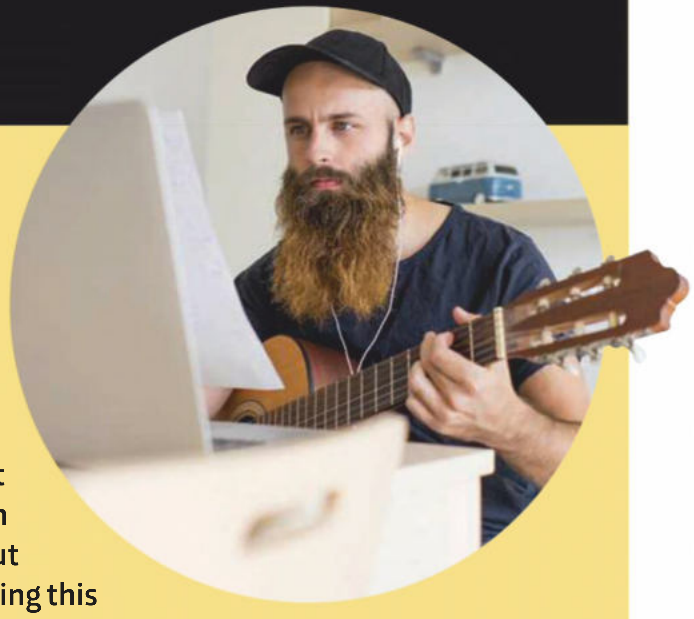
In 2019, the *Journal Of Human Sport And Exercise* reported on a 12-week exercise programme conducted in a Greek prison. In line with all the existing evidence, it found that participating inmates felt a greater sense of self-esteem and quality of life than those who didn't take part.

Now that COVID-19 has us all confined to our homes, we should all be doing the same as those Greek prisoners. Because as well as the health benefits and the regular dose of serotonin, getting a sweat on can also improve your work. Researchers at the University of Georgia found that even low-intensity exercise can boost your energy levels, making you better able to face your to-do list.

Follow YouTube videos or apps and mix your workouts between cardio, bodyweight exercises and yoga. The latter has been linked to improved working memory by researchers at Texas State University.



LEARN SOMETHING NEW



Work is likely to slow down for many people during the pandemic, but this in itself can create an opportunity. "Think about what else you can do during this period to develop another line to your work," says Cooper. "Maybe an IT course, maybe a language, do something to keep yourself cognitively active. You might never get this kind of window to learn something again. Use it."

As well as bolstering your long-term employability, lifelong learning is proven to improve happiness as well as cognitive traits like memory. And the literature is full of tips to help you learn more effectively.

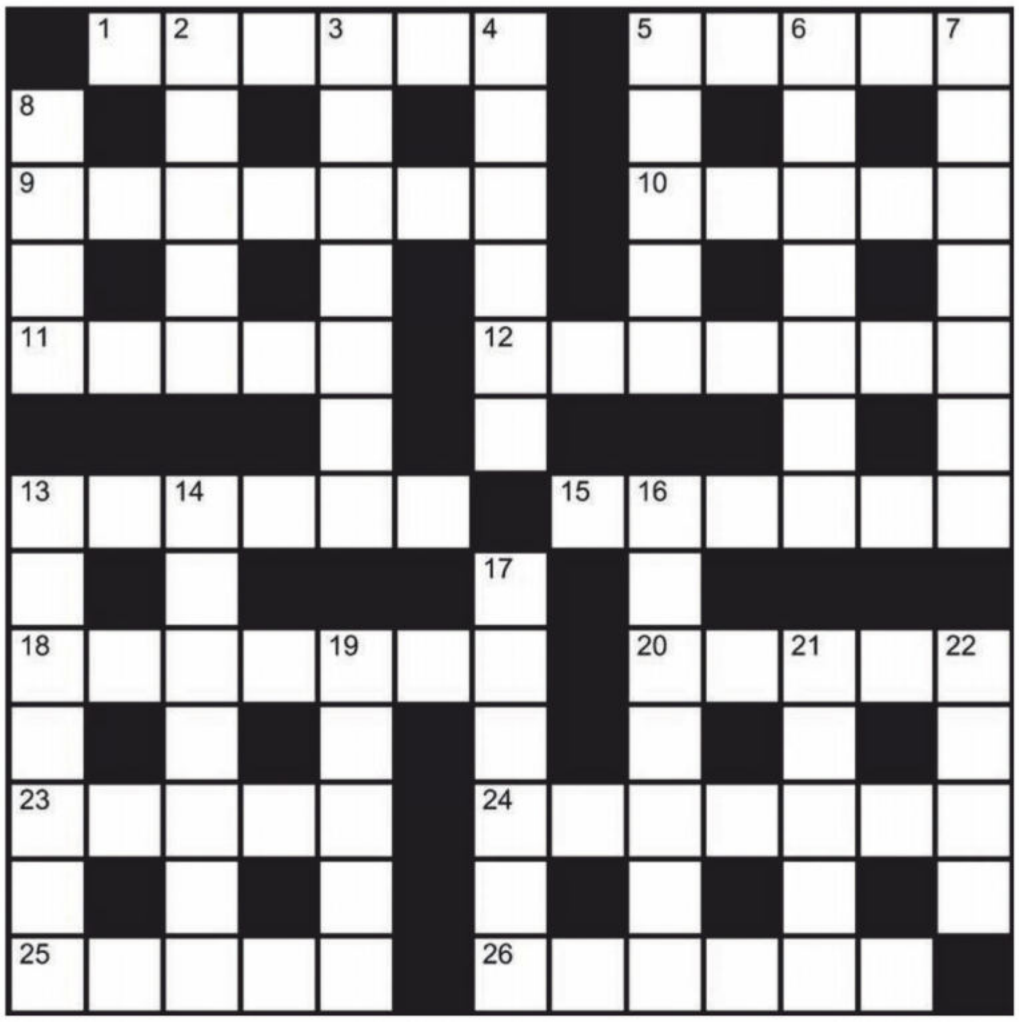
One of the most important tips is to rest after acquiring new information. This seems to allow your memory to consolidate what you've just learned. And a 2019 study in the journal *Current Biology* found that even taking regular 10-second breaks while you're learning can improve your ability to pick up new skills.

by IAN TAYLOR

Ian is a freelance science writer and editor.

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Wife constructs a tomb for marsupial (6)
5 African character in European country (5)
9 Royal house turns gold (7)
10 Fake coach has to go back (5)
11 Developing roots or trunk (5)
12 A looser form of spray (7)
13 Bishop, wet but clever (6)
15 Starting point by way of railway to get bird home (6)
18 Everything grey generated an aversion (7)
20 Forbidden to throw a boot (5)
23 Revolutionary exercise can be heard in the coop (5)
24 Attribute to a writer (7)
25 Clean key using heat (5)
26 Solitary pebbles, not hard (6)

DOWN

2 He admits being the proprietor (5)
3 Singer has nothing on an instrument (7)
4 Yarn to fix red hat (6)
5 It's hot at the end of three months (5)
6 Noble – a sporting venue (7)
7 Slip off in 24 hours to see show (7)
8 Points to reverse study (4)
13 Youngster to tolerate copper and boron (4,3)
14 Complaint as Milan works with eastern time (7)
16 Barrel and tin going round India's first city (7)
17 Surgical procedure creates a diversion (6)
19 Pure exchange rate's last currency (5)
21 Fish by first stream (5)
22 Old soldiers get a sign (4)

ANSWERS

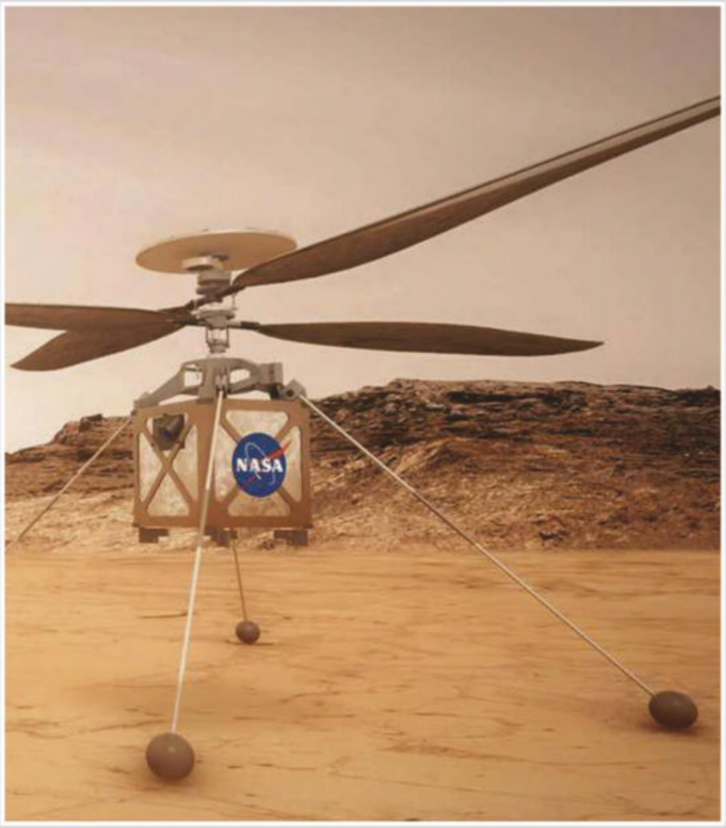
For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

GETTY IMAGES

NEXT ISSUE

MARS HELICOPTER

How this innovative chopper will take flight on the Red Planet.



PLUS

EYE ON THE SKY

Earth-bound telescopes are transforming our understanding of the cosmos. But we think they look pretty out-of-this-world too...

INTERVIEW: DR DAVID NUTT

In conversation with the eminent neuropsychopharmacologist.

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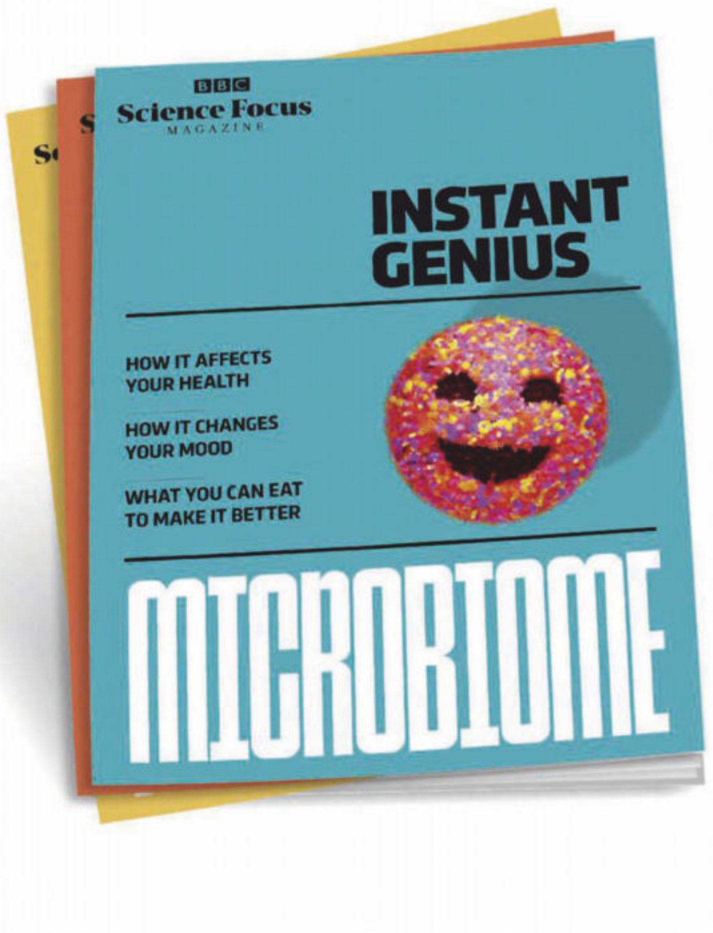
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A SCIENTIST'S GUIDE TO LIFE

HOW TO GROW INDOOR PLANTS

STUCK AT HOME AND CULTIVATING A HOUSEPLANT HABIT? BOTANIST **ALASTAIR CULHAM** EXPLAINS HOW TO KEEP THEM HAPPY, HEALTHY AND ALIVE...

LET THERE BE LIGHT

Light is the most important environmental factor to keep houseplants healthy. They need it for photosynthesis. If you've got decent light levels, they will photosynthesise more than they respire. If they didn't, they wouldn't grow.

CONSIDER YOUR WINDOWS

When the Sun is shining through south-facing windows, you get the most intense light. So that's where you put your cacti and bromeliads. North-facing windows rarely get direct sunlight, so this is where you put plants intolerant of bright light, so things like maidenhair fern. East- and west-facing windows get intermediate light levels, so the epipremnums and tradescantia do well.

LED LIGHTS HELP PLANTS GROW

Modern cool white LED lights give off a much more balanced daylight light spectrum than old filament bulbs. So a plant that's directly under an LED is going to get a useful quantity of additional photosynthetic light.

NO WATER = POORLY PLANT

If you drought stress a plant, its stomata, the tiny slits on the surface of the leaves, close so it doesn't lose water. If the stomata are closed, it can't photosynthesise because carbon dioxide can't get in and oxygen can't get out. So getting the watering right is important. Water the compost thoroughly, then let it dry out to the point where the top two or three centimetres are dry to the finger. Then it's time to water most plants again.

GIVE A NUTRIENT BOOST

Most composts used for growing houseplants will have had their nutrients leached out by watering within six to eight weeks. Through the summer, when there's plenty of light and reasonable warmth, I dilute liquid fertiliser down to about one tenth of the recommended strength and use that in my weekly watering.

GIVE YOUR PLANTS A FRESH START

If your plant is looking unhappy, repot it and give it some fresh soil. Houseplant compost is not a living soil. You've not got earthworms going through it to break it up. Repotting is about restoring the soil structure. The more compact the soil is, the harder it is for water to get through and the less oxygen gets in, so the less healthy the roots are.

HOUSEPLANTS KEEP YOUR HOME'S AIR HEALTHY

The biggest contribution houseplants make to the air is increasing the humidity, which is often low in centrally heated houses. There is also strong evidence that plants help with mental wellbeing – and that has a positive impact on your immune system.

DO YOU ALWAYS KILL PLANTS? THERE IS HOPE...

Spider plants and tradescantias are particularly robust. Cacti are the perfect plants if you're a forgetful waterer. Put them on a sunny windowsill and don't worry. Phalaenopsis, the moth orchids, have fleshy leaves and are about as tolerant of drought as most cacti. You just water them when they go a bit limp. SF

ALASTAIR CULHAM

Alastair is associate professor of botany at the University of Reading. He leads the @MyGreenStudy project aimed at getting houseplants into student homes

Interviewed by Andy Ridgway.

NEED TO KNOW...

1

The two things plants need are light and water.

2

Free phone apps, like Lux Light Meter, can measure light to help you place plants correctly.

3

Do you neglect plants? Cacti and spider plants will forgive you.

ILLUSTRATION: CATHAL DUANE

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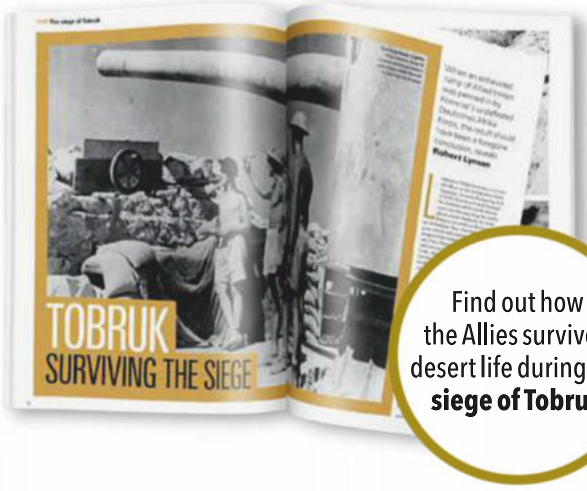
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